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Summary

With the development of information technology, the increase of international capital flows, and the liberalization of emerging markets, international investments have become more and more prevalent in the last few decades. At the same time, international securitized real estate markets have experienced rapid growth and extensive development. Investors have paied more attention to international securitized real estate markets seeking extra diversification benefits. Although there has been some studies investigating the international diversification benefits in real estate markets, few of them have properly considered the problems of multiple structural breaks and the heteroskedasticity. This research tries to bridge the gap between.

This study investigates the long-run relationships and short-term linkages in international securitized real estate markets with the consideration of structural breaks and the heteroskedasticity. Five major securitized real estate markets are examined, including the US, UK, Japan, Hong Kong and Singapore, in a time span of 1990 to 2006.

With the consideration of the structural breaks and the heteroskedasticity, both the long-run cointegration relationships and short-term lead/lag interactions and comovements in these securitized real estate markets are investigated. Empirical results suggest that these securitized real estate markets are more cointegrated after 1998, indicating a reduction in the benefits of international diversification in these markets. The Regime-dependent Asymmetric

Dynamic Covariance (RDADC) model shows that there are significant short-term market spillovers in both returns and volatilities. The asymmetric effects are detected as well. Furthermore, the scale parameters for regime changes are highly significant, indicating the importance of taking into consideration of the time-varying nature of the volatility transmission mechanism.

The research findings in this study provide valuable insights for academic researchers and professional investors to understand the long-run relationships and short-term comovements in international securitized real estate markets. Some of its applications to the asset allocation, such as the risk-minimizing optimal portfolio weights and the optimal hedge ratios, are discussed in this research as well.

Chapter 1
Introduction

1.1 Background and Conceptual Framework

Modern portfolio theory (MPT) proposed by Markowitz (1959) models the return of an asset as a random variable and a portfolio as a weighted combination of assets; the return of a portfolio is thus also a random variable and consequently has an expected value and a variance. Risk is identified with the standard deviation of portfolio return. Under the assumption of risk averse, the MPT theory shows that, if several portfolios have identical expected returns, a rational investor will choose the one which minimizes risk. In addition, the MPT theory also predicted that investors are able to reduce the aggregate risk of a portfolio by including the right assets. That is, risk is able to be reduced through diversification.

Since the inception of MPT, many researchers have studied and attempted to model the benefits of establishing diversification strategies for portfolio investments. Initial work focused on potential gains from combining different stocks into a single portfolio, but latter research has been extended into bonds, currencies, and real estate. With the development of information technology and liberalization of the emerging markets in the last few decades, international capital flows has been increased dramatically, raising the issue of international diversification (see Solnik, 1974; Bailey and Stultz, 1990; Liu, 1997; among many others).

In contrast to the abundant research works in international diversification with stocks and bonds market, researchers have not paid enough attention to diversification in international real estate market. The major reason is that the investment in real estate is usually lumpy and lack of liquidity, which is not favorable to most investors. Furthermore, foreign investment in real estate is very likely to be subjected to rigorous policy constraints in different countries. As a result, although real estate has already been well recognized as an efficient diversification class because real assets are unique, geographically segmented and less correlated with stock markets and other financial assets, the international diversification in real estate markets did not receive much attention until the 1990s.

Fortunately, the securitization of real estate markets and the deregulation in many emerging countries have created a convenient means of investing in international real estate assets. According to the data from Global Property Research (GPR), the capitalization of global securitized real estate market has reached 1,008 billion USD by November 2006, which is 6.2 times of the size in 1990 and is still expanding fast. The growing size of the securitized real estate markets has also been accompanied by a growing body of empirical research attempting to identify the diversification benefits through securitized real estate markets. A substantial body of real estate literature has demonstrated the important role played by securitized real estate as an asset class in both global mixed-asset portfolios and real-estate-only portfolios (see Asabere et al., 1991; Eichholtz, 1996; Conover et al., 2002; among others).

It is noticed that early studies on the diversification benefits in international securitized real estate markets have heavily relied on the analysis of correlation coefficients between different markets. With the development in statistics and econometrics, later studies have moved to analyze the long-run cointegration relationship and the short-term lead/lag interactions and comovements in international securitized real estate markets. Clarifying the issue on segmentation versus cointegration is important because market integration implies reduced or no diversification benefits and portfolio managers need such information so that appropriate diversification strategies can be implemented. On the other hand, understanding the short-term lead/lag interactions and comovements is also critical to investors and portfolio managers who intend to gain diversification benefits in international markets. Specifically, investment and hedging strategies could be more effective if the nature of market interactions were better understood. Furthermore, this is also important to policy makers, since the aspects of market interaction that promote efficiency could be facilitated, whereas those with undesirable side effects could be controlled.

Being aware of the importance of the long-run relationships and the short-term linkages in international markets, a number of studies have emerged in the last decade trying to identify the diversification benefits in international securitized real estate markets. However, the existing studies usually fail to accommodate two critical problems in their studies: the structural break and the heteroskedasticity.

As has been pointed out by Perron (1989), the existence of a structural break can affect the stationary properties of a time series. Gerlach et al. (2006) have also demonstrated that failure to consider a structural break will lead to erroneous conclusion about the cointegration. Therefore it is necessary to incorporate structural breaks into the investigation of international diversification benefits. Many studies have tried to circumvent this problem by dividing the sample period into several sub periods based on some pre-specified arbitrary break dates. Other studies, however, try to utilize statistical tools to test for a single break in the market. To the best of author's knowledge, there is no research to date that considered multiple structural breaks in international securitized real estate markets. The later is essential to determine both long-run relationship and short-term lead/lag structure in the markets. This research attempts to investigate the multiple structural breaks in international securitized real estate markets and the implication for long-run cointegration relationships and short-term linkages.

Another problem concerning the modeling of international diversification is the heteroskedasticity in the asset returns. In finance, heteroskedasticity usually refers to the time-varying characteristic of variances. Conventional asset pricing models and VAR models do not capture the time-varying nature of the variances of asset returns. The relationships in assets were first investigated only in the returns (first moment), assuming that the volatilities (second moment) are constant. However, a large number of empirical studies show that the conditional variances and covariances of stock market returns vary over time and exhibit volatility clustering behavior. Engle's (1982) ARCH model was the first formal model which captures the stylized fact of time-varying variances. ARCH model was soon extended to generalized ARCH (GARCH) model by Bollerslev (1986). In 1990s, the development of multivariate GARCH (MGARCH) has made it possible to simultaneously investigate lead/lag interactions and comovements in both returns and volatilities of different assets or markets. Recently, some studies have applied the MGARCH framework to international real estate markets, and found substantial evidence of spillovers in both returns and volatilities (see Liow et al., 2003, 2006; Chen and Liow, 2005; Michayluk et al., 2006; among others). However, a common problem associated with all ARCH type models, as argued by Lamoreux and Lastrapes (1990), is that the ARCH estimates are seriously affected by structural changes. On the other hand, the literature in regime switches (see Hamilton, 1989; Cai, 1994; among others) has also demonstrated that the presence of structural breaks will affect the short-term information transmission patterns. Unfortunately, most of the existing MGARCH models do not accommodate the problem of structural breaks. This research tries to bridge this gap to allow for the volatility transmission mechanism to change over time.

1.2 Research Objective and Expected Contribution

This research aims to investigate the long-run relationships and short-term linkages in international securitized real estate markets with the consideration of structural breaks and heteroskedasticity. The specific objectives of this research are:

(1) to identify multiple structural breaks in international securitized real estate markets;

(2) to investigate the long-run relationships in international securitized real estate markets with the consideration of structural breaks;

(3) to develop a Regime-dependent Asymmetric Covariance Dynamic (RDADC) model to

examine the short-term lead/lag interactions and comovements in international securitized real estate markets, allowing for the volatility transmission mechanism to be regime dependent (time-varying);

In particular, this research contributes to literature and investors' understanding in three aspects: a) based on new methods, this research is the first research that tries to identify multiple structural breaks in international securitized real estate markets and will provide new evidence on securitized real estate market behavior under different market environments; b) it links structural breaks to the long-run relationships of the securitized real estate markets, which is essential to global investors who are focusing on the long-run investment horizon in these markets; c) it develops a RDADC model that is able to capture the short-term return and volatility transmission with the presence of multiple structural breaks, which is important in determining optimal portfolio weights and making hedging strategies in these markets.

1.3 Research Data

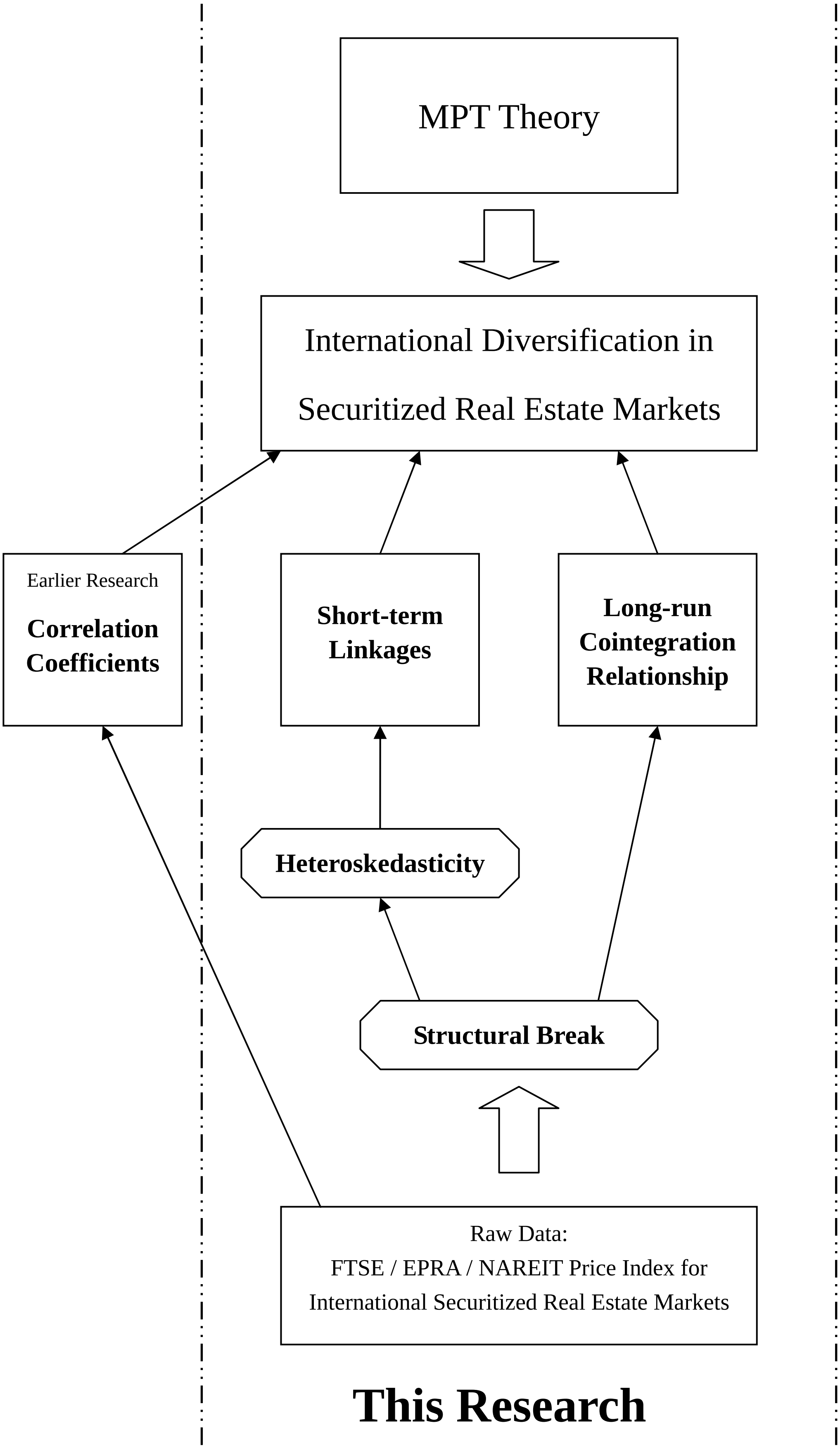
This research investigates five major securitized real estate markets in the world, namely the United States (US), United Kingdom (UK), Japan (JP), Hong Kong (HK), and Singapore (SG). According to the data from Global Property Research (GPR), the capitalization of these five markets is 651.22 billion USD by the end of Nov 2006, which is nearly 65% of the world property stock market. The raw data used in this study are daily price indices for these markets from 1/1/1990 to 6/30/2006. The FTSE / EPRA / NAREIT global real estate indices are collected from DataStream based on US dollar currency, and are converted into natural logarithms. The FTSE / EPRA / NAREIT global real estate indices are designed to track the performance of listed real estate companies and REITs worldwide, and are used extensively by investors worldwide for investment analysis, performance measurement, asset allocation, portfolio hedging and for creating a wide range of index tracking funds. The returns for each securitized real estate market are expressed in percentages computed by multiplying the first difference of the logarithm of property stock market indices by 100. The weekly volatility proxy series are constructed by computing the range of the logarithms of the daily price indices over a week (following Parkinson, 1980; Brunetti, 2003).

The detailed description of the data used in this research and brief characteristics of securitized real estate markets are presented in Chapter 3.

1.4 Research Methodology

Figure 1.1 provides an overview of the research framework of this study.

Figure 1.1 Framework and Flowchart for This Research



Briefly, there are three important methodologies:

(a) The Bai and Perron (2003) method for identifying multiple structural breaks in securitized real estate markets;

(b) The Johansen's (1988, 1991, 1994) cointegration test, Bierens's (1997) and Breitung's (2002) non-parametric cointegration tests for analysis of long-run relationships between securitized real estate markets;

(c) The Regime-dependent Asymmetric Dynamic Covariance (RDADC) model which allows for the volatility transmission mechanism to be regime dependent (time-varying), to assess the short-term lead/lag interactions and comovements in these markets.

The detailed discussion of the empirical methodologies appears in Chapter 4 and Chapter 5.

1.5 Organization

This study covers six chapters.

Chapter 1 outlines the background, research data, research objectives, data, and and methodologies.

Chapter 2 reviews the literature on international diversification and its application to the real estate markets. It first reviews the concept and early studies in this field, which mainly focused on the analysis of correlation structure between different markets. Second, the concept, methodology, and empirical evidence of structural breaks and its impact on long-run relationships in international diversification are reported. The third part reviews the literature on heteroskedasticity and its application to the short-term market interaction and comovements.

Chapter 3 describes the data used in this research. It first introduces the sample securitized real estate markets, followed by a discussion of the price indices, returns, and volatility proxies. The descriptive statistics are also reported in this chapter.

Chapter 4 is the first empirical part of this research. The Bai and Perron (2003) method is used to identify possible structural breaks in both price and volatility indices in the sample securitized real estate markets. The long-run relationships in these markets are then examined with the consideration of the structural breaks.

Chapter 5 continues with the second part of empirical investigation. The Regime-dependent Asymmetric Dynamic Covariance (RDADC) model is developed to investigate the short-term lead/lag interactions and comovements in the sample securitized real estate markets. Furthermore, the implications on portfolio managements are also discussed, such as the risk-minimizing optimal portfolio weights and the optimal hedging ratios.

Chapter 6 concludes this research. The major findings and implications are summarized in this chapter. The limitations and suggestions for future work are also discussed.

Chapter 2

Literature Review

2.1 Introduction

This chapter reviews the literature of methodologies and empirical studies related to this research. Section 2.2 reviews the background in international diversification and the early works in securitized real estate markets. Section 2.3 reviews the theory on structural breaks and its application to the long-run relationships in financial markets and the securitized real estate markets. The empirical studies investigating the short-term lead/lag interactions and comovements in international financial markets and securitized real estate markets are summarized in Section 2.4. The last section concludes.

2.2 International Diversification: Concept and Earlier Studies

Since the inception of MPT, many researchers have attempted to model the benefits of establishing diversification strategies for portfolio investments. In terms of the international diversification, most of the earlier studies focused on the correlation coefficients in different types of assets as well as international markets (see Solnik, 1974; Bailey and Stultz, 1990; Liu, 1997; among many others). However, later evidence suggests that international diversification with stocks and bonds is least effective when investors need it the most. Bertero and Mayer (1990), King and Wadhwani (1990) and King, Sentana and Wadhwani (1994) find greater integration of world stock markets in the period surrounding the crash of 1987. Longin and Solnik (1995) find increased correlation of international stock markets when stock market volatility increases from 1960 to 1990. Sinquefield (1996) questions the wisdom of international stock diversification in general. Using the Europe Australia Far East (EAFE) stock portfolio, he does not find any benefits from international stock diversification, unless an investor concentrates on value and/or small firm stocks overseas.

In spite of the abundant research in the international diversification with stocks and bonds market, researchers have not paid enough attention to the diversification in international real estate market until the 1990s. Fortunately, the securitization of real estate markets and the liberalization of many emerging countries have created a convenient means of investing in international real estate assets. The growing size of the securitized real estate markets has also been accompanied by a growing body of empirical research attempting to identify the diversification benefits through securitized real estate markets. A substantial body of real estate literature has demonstrated the important role played by securitized real estate as an asset class in both global mixed-asset portfolios and real-estate-only portfolios (see Asabere et al., 1991; Barry et al., 1996; Eichholtz, 1996; Liu and Mei, 1998; Wilson and Okunev, 1996; Conover et al., 2002; among others).

Earlier studies on the diversification benefits in international securitized real estate markets have relied heavily on the analysis of correlation structure (correlation coefficients) between different markets. Table 2.1 summarizes the key studies within this scope. For example, Asabere, Kleiman and McGowan (1991), in a study on the role of indirect property holdings in a mixed asset portfolio over the time period from 1980 to 1988, demonstrate that there are benefits to international diversification of real estate assets. These researchers find low positive correlations between U.S. real estate investment trusts (REITs) and international real estate equities. This finding is supported in a study conducted by Hudson-Wilson and Stimpson (1996). They examine the inclusion of U.S. securitized real estate in Canadian property portfolios over the period of 1980 to 1994, finding that Canadian investors would have benefited by the inclusion of U.S. real estate in their portfolios. In a more extensive study that includes nine countries from 1985 to 1994, Eichholtz (1996) finds significantly lower cross-country correlations for real estate returns than for either common stock or bond returns—implying greater segmentation in real estate than other assets. Eichholtz suggestes that a possible reason for the lower correlations for real estate may be that real estate is more influenced by local factors than is the case for either stocks or bonds.

Table 2.1 Empirical Evidence of Diversification in International Securitized Real Estate Markets

Panel A: Mixed-asset Portfilio

Year	Author(s)	Data	Results
1991	Asabere et al.	IREI, NAREIT, 19 countries, 1980-1988	International property investments are negatively correlated with US T-Bills and only slightly positively correlated with corporate and government bonds and REITS
1992	Kleiman and Farragher	IREI,MSCI,NAREIT,19 countries, 1980-1990	International property investments have a superior return but more risky compared to US REITs. The world real estate index has higher price earnings multiples but US REITs performs better if dividend yields are included
1996	Barkham and Geltner	NAREIT, NCREIF, JLW, FTA, S&P 500, FTA 500, 2 countries (US and UK), 1969-1992	Find indirect real estate to be more correlated with the stock market than direct real estate. Conclude price discovery occurs in both US and UK indirect markets and takes about a year to impact direct markets

Table 2.1 Empirical Evidence of Diversification in International Securitized Real Estate Markets (Continued)

Year	Author(s)	Data	Results
1996	Barry et al.	IFC, Salomon Brothers, Real Estate (9 emerging), Stock (22 developed + 26 emerging), 1989-1995	Increasing allocations to emerging real estate markets will improve portfolio performance
1996	Eichholtz	GPR, MSCI, Salomon Brothers, 9 countries, 1985-1994	Correlation coefficients between international real estate are significantly lower than stocks and bonds. International property stock portfolio outperforms international stocks and bonds portfolio
1996	Eichholtz and Koedijk	GPR, NAREIT, MSCI,Salomon Brothers,25 countries, 1987-1996	Low correlation coefficients. Regional property stocks also have low correlation coefficients compared to stock market
1997 (a)	Eichholtz	GPR, NAREIT, MSCI,Salomon Brothers,25 countries, 1987-1997	Investigate the correlation of property stock market with stock market (within each country). Correlation coefficients vary by region. Asian markets are highly correlated; European markets have low correlation coefficients
1997	Hamelink et al.	NAREIT, NCREIF, BZW, FTA, IPD, S&P 500, Lehman Brothers, 2 countries (US and UK), 1978-1995	Conclude that in the US the best inflation hedge is indirect real estate (REITs) and in the UK it is stock investment
1997	Liu et al.	IDC, BOE, Nikkei, 7 countries, 1980-1991	Find no evidence that the real estate stocks are any better at inflation hedging than the stock markets in most countries with the exception of France
1997	Mull and Soenen	NAREIT, MSCI, Salomon Brothers, G7 countries, 1985-1994	Find strong positive correlation between most countries and US REITs. Adding US REITs only marginally enhance the portfolios. US REITs provide improved portfolio performance in the latter period
1998	Gordon et al.	GPR,NAREIT,S&P500, Lehman Brothers,14 countries, 1984-1997	Cross-country real estate stocks are not as highly correlated as general stocks. Including international real estate stocks improve the portfolio performance.
1998	Liu and Mei	NAREIT, IDC, BOS,FTSE,6 countries, 1980-1991	Within-asset-class correlation is lower than between-asset-class correlation. Benefits are more pronounced at lower risk-return levels.
1999	Gordon and Canter	GPR, NAREIT, MSCI, 14 countries, 1984-1997	Correlation coefficients are not stable over time. However, portfolios that include international real estate stocks outperform those that do not
1999	Stevenson	DataStream, 16 countries, 1985-1998	International bonds enter at lower risk levels and stocks enter at higher levels of the efficient frontier. International real estate proxy only enters with a very small allocation at the mid risk-return level.
2000	Stevenson	DataStream, NAREIT, NCREIF, 10 countries, 1978-1997	Hedged series is significantly less volatile than the indirect series but more volatile than the direct real estate proxies. Correlation coefficients are low but even lower if hedged indices are used. Including international real estate stock improve portfolio performance
2002	Maurer and Reiner	DataStream, MSCI, NAREIT, BOPP, 5 countries (France, Germany, UK, Switzerland, and US),1985-2001	Integrating international real estate stocks into the portfolios enhances performance; as does currency hedging

Table 2.1 Empirical Evidence of Diversification in International Securitized Real Estate Markets (Continued)

Year	Author(s)	Data	Results
2002	Conover	NAREIT, MSCI, S&P, 6 countries (Canada, France, UK, Hong Kong, Japan and Singapore), 1986-1995	Find lower correlation coefficients with foreign real estate companies
2002	Hamelink and Hoesli	Salomon Smith Barney, Exchange Stock Index, 21 countries, 1990-2002	Cross-correlation coefficients for the indirect real estate are lower than stock markets. Over time, correlation coefficients for stocks are increasing but indirect real estate is remaining constant
2002	Lizieri et al.	GPR, DataStream, 12 European Union countries, 1984-2001	Eurozone property companies are less correlated than stock markets. They did not converge as rapidly in the run up to European monetary union as the general stock markets
Panel B: Real-estate-only Portfolio			
1990	Giliberto	Salomon-Russel, 11 countries, 1985-1989	Find correlation coefficients are relatively low. Western European investments dominate lower risk and return portfolios, while Japan dominates higher risk and return portfolios
1993	Eichholtz et al.	Salomon-Russel, BOPP,ISB,AG NAREIT, 12 countries, 1985-1990	Find a continental factor for the European and North America property markets. Japan is independent while UK has similarities with both continental Europe and the Far Eastern countries. Conclude need to invest across continents for optimal international diversification
1996	Addae-Dapaah and Boon Kion	Exchange Indices, 9 countries, 1977-1992	Find low correlation coefficients for most countries. Find significant instability in the correlation coefficients across time
1996	Hudson-Wilson and Stimpson	Public Index and some proprietary source, 2 countries (US and Canada), 1980-1994	Canadian investors would have been better off adding some US real estate investments to their portfolios of Canadian real estate assets. The results suggest that there is much to be gained by complementing Canadian risk/return portfolio characteristics with some specific investment behaviors found in the US real estate markets and perhaps in other international markets.
1997 (b)	Eichholtz	GPR, Europe, North America, Far East, 1984-1997	Find low correlation coefficients for regional data and higher correlation coefficients by property type. Residential property shows the highest return and lowest volatility and correlation with other property types
1997	Eichholtz et al.	GPR, 30 countries, 1984-1995	Find domestic portfolios outperform the international direct companies based on Sharp ratio and Jensen's alpha.
1999	Wilson and Okunev	NAREIT, FTSE, FTAP, S&P 500, Dow Jones, 3 countries (US,UK,and Australia), 1969-1993	Find no evidence to suggest long co-memories between stock and property markets in the United States and the United Kingdom, but some evidence of this in Australia. Find property stock markets are segmented.
2001	Pierzak	Salomon Smith Barney, 21 countries, 1993-2001	Find low correlation coefficients in interntional securitized real estate markets.
2002	Bigman	GPR, US, Europe, Japan and Non-Japan Asia, 1983-2001	Finds low correlation coefficients. The internatinoally diversified efficient portfolios outperform domestic ones.

With the development in statistics and econometrics, later studies have focused on the long-run cointegration relationship and the short-term lead/lag interactions and comovements in international securitized real estate market. However, these studies usually fail to accommodate two critical problems: the structural break and the heteroskedasticity. The next two sections will address these two issues respectively, and discuss their impacts on the investigation of international diversification. Empirical works on long-run cointegration tests and short-term linkages of international securitized real estate markets will also be reviewed in the following two sections.

2.3 Structural Breaks and Long-run Relationships

2.3.1 Concept and Background

For decades, researchers in economics and finance have been interested in testing structural breaks in macroeconomic and financial time series and identifying the substantial influence of such breaks. One of the pioneer works is the Chow (1960) test for structural breaks on the pre-assumed dates using an autoregressive model of time series. In reality, however, people do not observe this “known” break date. The development of statistics and econometrics theory has finally made it possible for researchers to deal with a single unknown break and even multiple unknown breaks in time series.

A debate concerning the dynamic properties of financial time series has been going on since Nelson and Plosser published their stimulating article in 1982. The primary issue involves the long-run response of a trending data series to a current shock to the series. The traditional view holds that current shocks only have a temporary effect and that the long-run movement in the series is unaltered by such shocks. Nelson and Plosser (1982) challenge this view and argued, using statistical techniques developed by Dickey and Fuller (1979, 1981), that current shocks have a permanent effect on the long-run level of most macroeconomic and financial aggregates. In other words, the traditional trend-stationary representation is rejected due to shocks in certain time period.

There are some other studies, including Campbell and Mankiw (1987, 1988), Clark (1987), Cochrane (1988), Shapiro and Watson (1988), and Christiano and Eichenbaum (1989), which argue that current shocks are a combination of temporary and permanent shocks and the long-run response of a series to a current shock depends on the relative importance or size of the two types of shocks. Later studies have also cast some doubt on Nelson and Plosser’s conclusion. For example, Perron (1988, 1989) argues that if the years of the great depression are treated as points of structural change in the economy and the observations corresponding to these years are removed from the noise functions of the Nelson and Plosser data, then a “flexible” trend-stationary representation is favored by 11 of the 14 series. Similarly, Perron shows that if the first oil crisis in 1973 is treated as a point of structural change in the economy, then one can reject the unit-root hypothesis in favor of a trend-stationary hypothesis for postwar quarterly real gross national product (GNP). These results imply that the only observations (shocks) that have had a permanent effect on the long-run level of most macroeconomic aggregates are those associated with the great depression and the first oil-price crisis.

2.3.2 Methodology of Testing Structural Breaks

Although there is no consensus on the influence of a shock on the long-run trend-stationary representation of a macroeconomic or financial time series, an increasing number of studies have started to take into consideration the possible structural breaks in their time series data. Parron (1989) has shown that the existence of a structural break in a time series can significantly affect its stationary properties.

As for the methodology, both the statistics and econometrics literature contain a vast amount of work on issues related to structural change in time series, most of which is designed for the case of a single change. Specifically, most of the studies rely on the unit-root testing procedure that allows for a known or unknown break in the trend function under the alternative hypothesis. For example, Zivot and Andrews (1992) have proposed a type of unit root test that allows for an estimated break in the trend function (a break in the intercept, slope or both – their models A, B, and C). Compared to the methods and empirical evidence with a single break, the problem of multiple structural changes has received considerably less but an increasing attention. Pesaran et al. (1996, 1998) develop a new approach to testing for the existence of a linear long-run relationship, when the orders of integration of the underlying regressors are not known with certainty. The test is the standard Wald or F statistic for testing the significance of the lagged levels of the variables in a first-difference regression. Related literature on the structural break methodology includes Perron (1989), Zivot and Andrews (1992), Andrews et al. (1996), Garcia and Perron (1996), Liu et al. (1997), Lumsdaine and Papell (1997), Morimune and Nakagawa (1997), Bai, Lumsdaine and Stock (1998), and Bai and Perron (1998, 2003a, 2003b, 2004), among others.

The latest methodology proposed by Bai and Perron (2003) considers estimating multiple structural changes in a linear model estimated by least squares. They derive the rate of convergence and the limiting distributions of the estimated break points. The results are obtained under a general framework of partial structural changes which allows a subset of the parameters not to change. They also address the important problems of testing for multiple structural changes: a sup Wald type tests for the null hypothesis of no change versus an alternative containing an arbitrary number of changes and a procedure that allows one to test the null hypothesis of, say, l changes, versus the alternative hypothesis of $l+1$ changes. The latter is particularly useful in that it allows a specific to general modeling strategy to consistently determine the appropriate number of changes in the data.

Another line of literature that related to the structural break investigates the change of market environment by the regime switch model. Introduced by Hamilton (1989), the regime switch model considers the evolution of volatility as Markov processes, with a default low-volatility state and a short lived high-volatility state. Under this approach, the parameters of a non-stationary time series are viewed as the outcome of a discrete-state Markov process.

The shifts are not to be observed directly but instead the probabilistic inference is drawn about whether and when the shifts have occurred, based on the observed behavior of the series. In other words, the regime switching models provide the estimates of the probability of a shift from low volatility regime to the high one, rather than the specific break date in the time series. Empirical studies that employed the regime switching methodology include, among others, Engle and Hamilton (1990), Goodwin (1993), Cai (1994), Engel (1994), Filardo (1994), Hamilton and Susmel (1994), Gray (1996), Garcia and Perron (1996), Hamilton and Lin (1996), Krolzig (1997), Schaller and van Norden (1997), Kim and Nelson (1998), Gradflund (2000), Ang and Bakaert (2002), Duan et al. (2002), Otranto (2005), and Gallo and Otranto (2005). Regime switch models provide substantial evidence for the time-varying information transmission patterns, and thus justify the introduction of structural breaks into GARCH framework to analyze the short-term lead/lag interactions and comovements. The application to international securitized real estate markets will be discussed in Chapter 5 in detail.

2.3.3 Empirical Evidence

(a) Identifying Structural Breaks

Generally speaking, empirical studies examining the possible structural breaks in the real estate market are not adequate. Most of the studies use a pre-specified break date that is based on other studies on macroeconomics or general stock markets. Many studies focus on the impact of Asian financial crisis on property markets, especially on the interdependence between real estate and other asset classes. For example, Renaud (2000) investigated the interdependence roles of real estate and banking in the Asian financial crisis, and another research by Renaud et al. (2001) suggested the real estate crisis during 1996/1997 in Thailand precipitated a domestic financial crisis whose large cost was further amplified by a currency crisis in 1997.

Only a few studies have applied the structural break methodology to the international real estate markets. Kallberg et al. (2002) apply the Bai, Lumsdaine and Stock (BLS, 1998) technology for identifying regime shifts in the securitized real estate markets in eight developing Far Eastern countries from 1992 to 1998. The countries they investigated include China, Hong Kong, Indonesia, Malaysia, Philippines, South Korea, Taiwan and Thailand. They search for the time around the crisis when the dynamics of the relation between the return and volatility of securitized real estate and equity shifted the most. Specifically, the BLS technique is used to search for a single break in a multivariate time series and specify asymptotic confidence intervals for the break point. They use this methodology to test for regime shifts in the linear relation between equity and real estate markets in each country separately. They find that regime shifts in volatility occur in the summer of 1997; however, most of the regime shifts in returns occur in the spring of 1998. Furthermore, they also find that equity returns cause real estate returns but the converse is not true, based on an analysis of Granger causality in these countries.

Gerlach et al. (2006) employ the unit root testing procedures developed by Zivot and

Andrews (1992) to test for the presence of a single structural break in weekly price indices of real estate securities in Japan, Hong Kong, Malaysia, and Singapore. The break is allowed in intercept, slope or both in the linear trend function. They found that all the test statistics are significant indicating a break date about mid to late 1997, which coincides with the Asian financial crisis. Specifically, the earliest break point is identified on 7/29/1997 in Malaysia, and the latest on 10/21/1997 in Japan.

Another approach to the investigation of structural breaks, i.e. the regime switch methodology, has recently been applied to the real estate markets. For example, Lizieri et al. (1998) test for the existence of the two-regime real interest rate in the U.S. REITs and U.K. property companies using a threshold autoregressive (TAR) model. Maitland-Smith and Brooks (1999) find that the Markov switching model is better able to capture the non-stationary features of their U.S. and U.K. commercial real estate return series than the TAR. Liow et al. (2005) formally explore the presence of regimes in real estate return and volatility using a set of international exchange-based real estate index data from the US, UK, Australia, Hong Kong, Japan and Singapore markets. They find that regime changes in international securitized real estate markets result in different states of the markets with different patterns of risk-return behavior and state interactions.

To the best of the author's knowledge, there is no research investigating multiple structural changes in real estate markets. This study tries to fill in the gap to provide empirical evidence for the multiple structural breaks in international securitized real estate markets, and the significant implications of the presence of multiple structural breaks on the long-run relationships and short-term return and volatility dynamics.

(b) Long-run Relationships of Real Estate Markets

Generally speaking, the empirical evidence of the long-run cointegration relationship of real estate markets is mixing. A body of literature suggesting that property markets are segmented, while other studies showing the opposite. At the same time, some studies have ignored the impact from possible structural breaks, whereas others used either an arbitrary break date to divide the sample into sub periods, or a statistical test for a single break along the sample period.

<u>(b1)Without Structural Breaks</u>

There has been many research works showing international property markets are segmented. For example, Ziobrowski and Curcio (1991) find substantial diversification benefits of US real estate assets to foreign investors. Sweeney (1993) investigates the investment strategy in European property markets, and also finds positive evidence of diversification benefits in European countries. Liu and Mei (1998) point out that international property markets are segmented and that there are benefits to international diversification in real estate.

Eichholtz et al. (1998) also find segmentation between continents but integration within continents. This is particularly so for Europe and true to a lesser extent for North America. They conclude that European investors would need to look outside Europe for diversification benefits. Interestingly, these authors do not find such a continental factor for the Asia-Pacific region. However, Eichholtz et al. (2001) suggest that, while there are benefits to international diversification, there is a tradeoff between the benefits and costs of such diversification. Their findings suggest that property investors can gain substantially in terms of reduced costs by investing in securitized property companies that concentrate on their local, domestic market.

Garvey et al. (2001) examined the linkage between the four largest securitized real estate markets in the Asia Pacific-Rim region; namely Australia, Hong Kong, Japan and Singapore. They find little evidence of common long-run trends based on the cointegration test. The results are further supported by the portfolio analysis, which found with the exception of Australia, significant improvements in portfolio performance can be obtained by an investor diversifying out of an all domestic portfolio into an internationally diversified portfolio in the Asia Pacific-Rim region.

In contrast to the studies that demonstrated segmentation in international real estate markets, there is some other evidence illustrating that international real estate markets are actually cointegrated. For example, using the Johansen cointegration methodology on appraisal based property data across three countries (US, Canada, and UK), Myer et al. (1997)

find that these series were highly cointegrated. Tarbert (1998) applies cointegration techniques for initial property portfolio selection and finds that the potential risk reduction benefits of property diversification by region and sector within the UK are more limited than previously thought. Case et al. (2000), using appraisal based property data over 22 countries, present strong evidence to support the notion of globalization of property markets.

(b2) With Structural Breaks

The evidence in the stock markets has already demonstrated that the presence of a structural break, such as the crisis, will have great impact to the market correlations and cointegration relationships. For example, Inoue (1999) proposed a cointegration rank test that has power against the trend-break alternative and found that money, income and interest rates are cointegrated around a broken trend. Sheng and Tu (2000) examined stock market data sampled before and during the Asian financial crisis. Their research suggested that stock markets were not cointegrated before the crisis of 1997, but that there was some degree of cointegration during the crisis.

As for the real estate markets, however, Gerlach et al. (2006) has pointed out that there exists relatively little research on the influence that the structural break has had upon capital flows within the property market and the associated long-run implications of it. There has been some interest among researchers on the impact of the Asian crisis on property markets, but such researchers have focused on the interdependence between real estate and other asset classes. For example, Renaud (2000) notes that the interdependent roles of real estate and banking in the Asian crisis has highlighted the conspicuous need for much better price and quantity monitoring of real estate cycles. Research by Renaud et al. (2001) suggests the real estate crisis during 1996/1997 in Thailand precipitated a domestic financial crisis whose large cost was further amplified by a currency crisis in 1997. Moreover, it was from this point that the crisis spread quickly to financial and property assets held in other economies. In contrast, a study by Kim (2000) on the Korean real estate market presents strong evidence to suggest that the real estate sector could not have been a major cause of the economic crisis in that country.

Tarbert (1998) raises concern over the dangers of using conventional correlation techniques in preliminary portfolio construction due to the temporal instability of such correlations, pointing to earlier work on this by Baum and Schofield (1991). They show that the instability correlation structure, such as the presence of a structural break, will have significant impact on the diversification benefits. The main difficulty revolves around the idea that, since correlation coefficients are temporally unstable, a well-diversified portfolio initially selected through correlation analysis in one period may not hold in subsequent periods.

Wilson and Zurbruegg (2003a) uses established methodologies to decompose driving factors affecting indirect property markets in Australia into their permanent and transitory components, paying attention to the impact of structural breaks. Various restrictions on the long-run cointegration matrix are also applied to identify those variables that may be considered drivers of property markets. Wilson and Zurbruegg (2003b) further investigate the international real estate market diversification and find mixed outcomes irrespective of whether direct or indirect property assets are being examined. Wilson and Zurbruegg (2003c) look into six securitized real estate market integration and find that not only are international real estate markets inter-linked, but that some large economies, such as the US and Japan, may have a significant influence over smaller markets. Wilson et al. (2007) examine the interdependence across securitized property markets by Inoue (1999) cointegration methodology with the structural time series procedure of Harvey (1989). The result indicate that there is some unifying force across international property markets and that this unifying force may stem from the United States. The results also suggest that, at least to some extent, shocks to securitized property markets produce a similar response to stock market shocks.

Gerlach et al. (2006) examine several Asia-Pacific real estate markets with their long-run cointegration relationship, with and without the effect of the 1997 Asian financial crisis. They find that failure to take into account the events of 1997 disguises the true nature of the long-run inter-linkages between these property markets. That is, if no consideration is given for the 1997 crisis, the real estate markets show no signs of integration; however, they are found to be significantly cointegrated when allowance is made for the crisis. Although these authors find significant long-run correlations among international real estate markets, they argue that, since property is location specific there would, on an intuitive level, be no reason to suppose that such markets should be linked. Quite significantly their research, in fact, suggests that world real estate markets are correlated and that this correlation is due, in part, to common exposure to fluctuations in the global economy, as measured by an equal weighted index of international GDP changes.

2.4 The Heteroskedasticity and Short-term Linkages

2.4.1 Concept and Background

Whilst the structural break is essential in modeling the long-run trend in time series, there is another important characteristic that widely exists in financial time series – heteroskedasticity. In statistics, a sequence or a vector of random variables is heteroskedastic if the random variables in the sequence or vector may have different variances. In financial market, a basic observation about asset return data shows that large returns (of either sign) tend to be followed by even larger returns (of either sign). This phenomenon is usually referred to as the clustering characteristic of volatility. In particular, volatility clustering is the tendency of large (small) changes to be followed by large (small) changes of either sign. In other words, the volatility of asset returns appears to be time varying and serially correlated, i.e. the heteroskedasticity.

Why is heteroskedasticity important? When using a variety of techniques in statistics, such as ordinary least squares (OLS), a number of assumptions are typically made. One of these is that the error term has a constant variance. This will be true if the observations of the error term are assumed to be drawn from identical distributions. Heteroskedasticity is a violation of this assumption. Since a large number of empirical evidence has already shown that the conditional volatility of stock market returns vary over time and exhibit volatility clustering behavior, it is critical to take into account of the heteroskedasticity in any asset pricing model that deals with asset returns. As has been pointed out by Tsay (2005), modeling the volatility of a time series to account for the heteroskedasticity can improve the efficiency in parameter estimation and the accuracy in interval forecast.

The most widely used technique in modeling volatility of asset returns is the Autoregressive Conditional Heteroskedasticity (ARCH) model proposed by Engle (1982). Prior to the introduction of ARCH, although researchers are aware of changes in variance, they use only informal procedures to take account of this. For example, Mandelbrot (1963a) use recursive estimates of the variance over time and Klien (1977) took five period moving variance estimates about a ten period moving sample mean. However, Engle's (1982) ARCH model is regarded as the first formal model which seemed to capture the stylized fact of time-varying variances.

2.4.2 Methodology

In Engle’s (1982) model, the variance of the current error term is a function of the variances of the previous time period’s error terms. This Moving Average (MA) assumption in the conditional variance relates the current error variance to the square of a previous period’s error, and thus accounts for the problem of heteroskedasticity. Bollerslev (1986) further develops Engle’s framework by extending the MA assumption to an ARMA (Autoregressive

Moving Average), and finally arrives at the generalized Autoregressive Conditional Heteroskedasticity (GARCH) model. Since then, hundreds of studies have emerged to apply the GARCH model to the financial market, and yielded fruitful results. By specifying a different representation in the conditional variance equation, several types of GARCH model have been developed. For example, the exponential GARCH (EGARCH) model of Nelson (1991), GJR-GARCH model of Glosten et al. (1993), Threshold GARCH (TGARCH) model of Rabemananjara and Zakoian (1993), etc. Noteworthy is that most of the extension from the original Bollerslev's (1986) GARCH model is intended to account for the asymmetric (leverage) effect that negative news often have greater influence on volatilities (see Black (1976), Christie (1982), Nelson (1991), among others).

Introduced by Engle et al. (1987), the GARCH-M model offers a means that links conditional market volatility and expected returns. Furthermore, the extension from univariate GARCH to multivariate GARCH (MGARCH) models represents a major step forward in the volatility modeling. The multivariate GARCH models have been among the most widely used time-varying covariance models. These models include the VECH model of Bollerslev, Engle, and Wooldridge (1988), the constant correlation (CC) model of Bollerslev (1990), the factor ARCH (FARCH) model of Engle, Ng, and Rothschild (1990), the BEKK model of Engle and Kroner (1995), the Asymetric Dynamic Covariance model (ADC) of Kroner and Ng (1998), and the Dynamic Conditional Correlation (DCC) model of Engle (2002) and Tse and Tsui (2002).

The GARCH family model is useful not only because it captures some stylized facts in financial time series, but also because it has applications to numerous and diverse areas. As has been summarized by Bera and Higgins (1993), the GARCH-type models have been widely used in asset pricing to test the CAPM, the ICAPM, the CCAPM and the APT; to develop volatility tests for market efficiency and to estimate time varying systematic risk in the context of the market model. It has been used to measure the term structure of interest rates; to develop optimal dynamic hedging strategies; to examine how information flows across countries, market and assets; to price options and to model risk premia. In macroeconomics, it has been successfully used to construct debt portfolios of developing countries, to measure inflationary uncertainty, to examine the relationship between exchange rate uncertainty and trade, to study the effects of central bank interventions, and to characterize the relationship between the macroeconomy and the stock market. Particularly in this research, we focus on the use of ARCH family models in examining the information flows across international securitized real estate markets.

However, a common problem associated with all ARCH type models, as argued by Lamoreux and Lastrapes (1990), is that the ARCH estimates are seriously affected by structural changes. One solution to this problem is the regime switch models (see Hamilton, 1989; Cai, 1994; among others), which has been mentioned in the previous section. However, the regime switching ARCH (sometimes called SWARCH) models provide merely the estimates of the probability of a shift from low volatility regime to the high one, rather than the specific break date in the time series. Other MGARCH models do not accommodate the problem of structural breaks. They assume that the volatility transmission mechanism does not change over time. This research attempts to bridge this gap to incorporate the multiple structural breaks into the MGARCH system to allow for the volatility transmission mechanism to be dependent over different market regimes.

2.4.3 Empirical Evidence

The GARCH family models have been applied to a wide range of time series analyses, and the applications in finance have been particularly successful in the last two decades. (see Bollerslev, Chou and Kroner (1992), Engle (2001), Poon and Granger (2003) for extensive surveys). A few studies have even extended these to the multivariate case (see, for example, Tse (2000), Tay and Zhu (2000) and Scheicher (2001)). Despite a huge amount of the empirical works with GARCH family models, only those studies investigating the international information flows in the stock markets and securitized real estate markets are reviewed in this section. Studies that used the GARCH family models to investigate interest rate, exchange rate and other macroeconomic time series are not reviewed here.

(a) General Stock Market

There have been numerous applications of the GARCH family models in investigating the transmission mechanism of stock price movements and volatility transmissions across international stock markets. For example, Eun and Shim (1989) find that innovations in the US stock market are rapidly transmitted to the rest of the world, although innovations in other national markets do not have much effect on the US market. Von Furstenberg and Jeon (1989) find that the correlation among the daily stock indices of the US, Japan, the United Kingdom, and Germany increased significantly after the crash of 1987. Hamao et al. (1990) find that daily price volatility spills over from the US to Japan and the UK, and from UK to Japan.

Theodossiou and Lee (1993) use a multivariate GARCH model to examine interdependencies across the stock markets in US, Japan, Canada and Germany. They find considerably weak, but statistically significant mean spillovers radiate from stock markets of the US to the UK, Canada, and Germany, and then from the stock markets of Japan to Germany. No relation is found between the conditional market volatility and expected returns. Strong time-varying conditional volatility exists in the return series of all markets. The own-volatility spillovers in the UK and Canadian markets are insignificant, suggesting that the conditional volatility of returns in these markets is "imported" from abroad, specifically from the US. Significant volatility spillovers radiate from the US stock market to all four stock markets, from UK stock market to the Canadian stock market, and from the German stock market to the Japanese stock market.

Similarly, Koutmos and Booth (1995) focus on the stock markets of New York, London, and Tokyo. They find strong evidence that volatility spillovers in a given market are much more pronounced when the news arriving from the last market to trade is bad. Furthermore, a before and after October 1987 crash analysis reveals that the linkages and interactions among the three markets have increased substantially in the post-crash era, suggesting that national markets have grown more interdependent. Susmel and Engle (1994) examine the timing of mean and volatility spillovers between New York and London equity markets. They find that the evidence of volatility spillovers between these markets is minimal and have a duration which lasts only an hour or so. The most significant effects surround the movement of share prices around the New York opening, but these results are not strong.

Koutmos (1996) investigates the dynamic interdependence of major European stock markets, including UK, France, Germany and Italy. He uses a multivariate VAR-EGARCH model to describe the lead/lag relationships and volatility interactions in these stock markets. He finds evidence of multidirectional lead/lag relationships in both first and second moment interactions. Furthermore, most of the volatility transmissions are found to be asymmetric. He also finds that European stock markets are integrated in the sense that they react not only to local news but also to new originating in the other markets, especially when the news is adverse. Kana (1998) uses an EGARCH model on data for the main European markets, and found significant information transmissions. Michelfelder (2005) analyzes the volatility of stock returns of seven emerging markets and compares them with the mature markets of Japan and US. By using the EGARCH specification with Skewed GED, he finds that US shocks are rapidly transmitted to the rest of the world.

Additionally, some other researchers have also investigated the intertemporal relation between expected returns and market risk (i.e. ARCH in mean effect). Pindyck (1984) claims that much of the decline in US stock prices during 1970s was due to the volatility increases. Bollerslev et al (1988) find that the conditional volatility of stock market returns significantly affects their expected value. Conversely, French et al. (1987), Baillie and Degennaro (1990), and Theodossiou and Lee (1994) find no relation between stock market returns and volatility.

The interdependence between the US, Japan and four Asian stock markets has been studied by Liu and Pan (1997). Liu and Pan conclude that the US market is more influential than the Japanese market in transmitting returns and volatilities to the four Asian markets. Bala and Premaratne (2003) employ several GARCH models to investigate the volatility co-movement between Singapore, Hong Kong, Japan, UK and US. Unlike the previous research which concludes that spillover effects are significant only from the dominant market to the smaller market, they find that it is plausible for volatility to spill over from the smaller market to the dominant market.

(b) Real Estate Markets

As for the real estate markets, studies investigating the short lead/lag interactions and comovements using GARCH model turn out to be inadequate compared to the abundant works in the stock markets. Only some studies after 2000 addressed this issue.

Garvey et al. (2001) have applied both Granger causality and GARCH approach to analyze the linkages in both the first and second moment of the return series in securitized real estate markets in Australia, Hong Kong, Japan and Singapore. They find little evidence of co-movement or influence between the markets on a bivariate basis. The primary exception occurs when contemporaneous observations are incorporated into the causality tests. In this case, with the exception of Japan, consistent evidence is found of bilateral causal relationships between Australia, Hong Kong and Singapore.

Liow et al. (2003) employ an extended EGARCH (1, 1) model and find weak mean transmission and minimal cross-volatility spillovers across the Asian and European property stock markets. Liow and Zhu (2005) take a causality perspective and find that international real estate markets are generally correlated in returns and volatilities contemporaneously and with lags. The US and UK markets significantly affect some Asian markets such as Singapore, Hong Kong, Japan and Malaysia in either mean or return volatility at different lags.

Chen and Liow (2005) develop a multivariate exponential GARCH in mean (MEGARCHM) model to investigate the transmission of returns and volatility among world stock market and major real estate markets, including Australia, Hong Kong, Japan, Singapore, United Kingdom, and the United States. They find some significant and multidirectional mean and volatility spillover effects, which indicate these real estate markets are reasonably correlated. They also construct total hedged return indices which are expected to filter out the general stock market impact and the results show that both mean and volatility correlations have been reduced to a large extent. Moreover, the volatility spillover effects are found to be more significant within Asian countries than across the world. That is, the real estate markets seem to exhibit a continental segmentation in general.

Liow et al. (2006) employ a multivariate GJR-DCC (1, 1) model to investigate the time-varying correlation dynamics of the real estate security and the stock markets in US, UK, Japan, Hong Kong and Singapore. The result indicates that significant variations and structural changes, in the correlation structure of the international real estate security and the stock markets, have occurred within the sample period between 1984 and 2006. They also find that there is a strong and positive connection between the real estate security market correlation and the conditional volatilities. Furthermore, the real estate security and the stock market correlations are linked while movements in the international real estate security market correlations follow closely the movements in the international stock market correlations or vice versa in some cases. Although the international real estate security market correlations have generally increased slightly over the long-run, they are still significantly lower than those of the stock markets. The diversification benefit to be obtained from investing in the international real estate security markets still remains.

Michayluk et al. (2006) construct synchronously priced indices of securitized property listed on NYSE and LSE and used a bivariate ADC model to examine dynamic information flows between the two markets. Their results indicate that the real estate markets in these two countries experience significant interaction on a daily basis, and positive and negative news impact the markets differently.

<u>(c) The Contagion Effect</u>

Finally there are also some studies that focused on the so called “contagion” effect in explaining the market comovements. For example, Wilson and Zurbruegg (2004) examine whether there was contagion from the Thai securitized real estate market to four other prominent Asia-Pacific property markets. They find that there was some contagion effect from Thailand to Hong Kong and Singapore during the period between early July and late October 1997. However, if the period includes the stock market crisis of late October 1997, there is little evidence for real estate market contagion, as it would seem that the impact of the equity markets were more relevant thereafter, in affecting other financial markets than the property markets themselves. Suliman (2005) studies the presence of contagion from Mexican exchange rate changes on US interest rates and Japanese exchange rates. Furthermore, the analysis of the spillover effects has been analyzed using several other econometric approaches. For example, wavelets are adopted by Lee (2004) who investigates the international transmission mechanism of the stock market movements, finding volatility spillover effects from the US to Korea, but not vice versa; a two-factor arbitrage pricing theory model before and after the 1997 Asian crisis is applied by Aquino (2005).

2.5 Summary

This chapter provides an integrated review of existing finance and real estate literature related to the present research. The main findings can be summarized as:

(a) There has been abundant research on international diversification in financial markets, such as stocks and bonds; whereas the international diversification in real estate has not become popular until the development of securitization made it convenient to invest in global real estate;

(b) Earlier studies on the diversification in international securitized real estate markets have mainly relied on the analysis of correlation structure (correlation coefficients) between different markets, while later studies have focused on analyze the long-run equilibrium relationship and the short-term lead/lag interactions and comovements in international securitized real estate market;

(c) The presence of structural break will significantly affect the empirical results in both long-run cointegration test and short-term lead/lag spillover analysis, but to date there is little empirical studies that have taken into consideration of multiple structural breaks in international securitized real estate markets;

(d) The wide existence of heteroskedasticity in financial time series has required researchers to model not only returns but also volatilities. The multivariate GARCH model is quite suitable of modeling time-varying conditional variances and covariances; but they fail to accommodate the problem of structural breaks. Therefore, an extension of the MGARCH model to allow for time-varying volatility transmissions is necessary.

Chapter 3
Research Data

3.1 Introduction

This chapter describes the data employed in this research. It begins with an overview of international securitized real estate markets investigated in this study, followed by a discussion of the price indices, return and volatility series, the descriptive statistics and some statistical tests. The final section concludes this chapter.

3.2 International Securitized Real Estate Markets

This study mainly focuses on international securitized real estate markets, rather than direct property markets. As has been pointed out by several previous studies, direct property series suffer from the syndrome of appraisal smoothing and, while de-smoothing techniques have been developed, there is some degree of subjectivity involved in the procedures (see Barkham and Geltner, 1995, 1996; Brown and Matsiak, 2000; Chaplin, 1997; Chau et al., 1999). In addition, problems of lot size and liquidity in direct property markets require data series of longer duration and higher frequency (to ascertain market integration) than are generally available (see Gerlach et al. 2006). Finally, even though differences will exist, a substantial amount of research shows that the direct and indirect property markets follow each other relatively closely. For example, Barkham and Geltner (1995) find price discovery to transmit from indirect to direct property markets with varying time lags in the US and UK real estate markets. Also, Kallberg et al. (2002) show using semi-annual data (albeit with relatively few observations) the correlation of price movements between the direct market and equity-listed property holding companies in Asia is relatively strong. These studies are also supportive of the findings by Myer et al. (1997) and Case et al. (2000) on direct property market linkages across international boundaries.

The securitized real estate markets in the United States (US), United Kingdom (UK), Japan (JP), Hong Kong (HK), and Singapore (SG) are investigated in this study. These five markets consist of the majority of the global real estate market. According to the data from Global Property Research (GPR), the capitalization of these five markets is 651.22 billion USD by the end of Nov 2006, which is nearly 65% of the world property stock market. Of them, US, UK and Japan are considered well established markets, while Hong Kong and Singapore are major Asian developing economies and have long-established track records of their listed property investment and development companies. Table 3.1 summarizes the general economic conditions and real estate market characteristics in these economies.

The remainder of this section gives a brief introduction of the securitized real estate markets in the US, UK, Japan, Hong Kong and Singapore.

Table 3.1 Economic Conditions and Real Estate Market Characteristics

		US	UK	JP	HK	SG
Economic Environment Indicators						
Population [a]	Million	298.21	59.67	128.08	7.04	4.33
GDP [a]	$Billion	12,487	2,227	4,663	172.6	110.6
GDP per capita [a]	USD	41,873	37,322	36,407	24,517	25,543
Growth rate (94-05) [a]	%	5.30	5.48	0.29	2.56	5.49
Exchange rate [a]	per USD	1	0.58	117.97	7.75	1.67
T-Bill Rate [a]	%	3.17	4.55	1.36[f]	3.65	2.04
Lending rate [a]	%	6.19	4.65	1.67	7.75	5.3
Consumer Price [a]	2000=100	113.4	112.8	97.8	93.4	103.3
Unemployment rate [a]	%	5.1	2.8	4.4	5.6	3.9
Stock Market						
Capitalization [b]	$Billion	14,266	2,412	3,041	715	145
Value Traded (VT) [b]	$Billion	15,540	2,151	2,273	332	88
VT/Capitalization [b]		1.09	0.89	0.75	0.46	0.61
No. of Companies [b]		5295	2311	3116	1029	475
Average firm size [b]	$Million	2694.29	1043.89	975.82	694.46	305.51
Real Estate Market						
Transparency rank [c]		3	4	26	7	9
Transparency tier [c]	1~5	1.24	1.24	3.08	1.5	1.55
Securitized Real Estate Market						
Capitalization [d]	$Billion	290.09	71.76	130.01	124.71	26.69
Listed Companies [e]		170	132	77	98	47
Property / Stock market [d]	%	2.52	2.20	2.95	14.07	13.12
P/E ratio [d]		37.7	28.6	40.2	8.6	12.7
Divident Yield [d]	%	3.96	1.98	1.12	2.24	2.54

Source:

[a] IMF country database and IMF International Financial Statistics Yearbook (2006)

[b] Standard & Poor’s Emerging Stock Markets Factbook (2004)

[c] Global Real Estate Transparency Index (2004)

[d] DataStream (2006)

[e] State Stock Exchange Website (2006, including REITs)

[f] Japanese government bond yield rate

(a) United States

Enjoying the largest economy in the world and with a landmass over two and a half times the size of the EU, America is not a country a real estate investor should ever overlook. In US, the securitized real estate market is mainly composed of Real Estate Investment Trust (REITs) that are subject to strict leverage and dividend payouts constraints, which are different from the other four markets. REITs were established by Congress in 1960 as a means of allowing smaller, retail investors to participate in the commercial property markets. REITs are generally regarded as attractive additions to investment portfolios because there is a relatively low correlation between REITs and the returns of other market sectors.

The market capitalization of REITs in US has grown more rapidly than the general stock market, as a result of consolidation through mergers and acquisitions. The total market capitalization of publicly traded equity REITs amounted to 399 billion USD in Nov 2006, which is more than 45 times of 8.73 billion USD in 1990 (data from NAREIT, the National Association of REITs). The rapid growth of US REITs in the last few decades can also be attributed primarily to a series of important policies. First, with the Tax Reform Act of 1986 (TRA 86), REITs not only had the tax advantage, but also were given greater managerial control over their properties and could make substantial investment decisions internally rather than externally. TRA 86 allowed REITs management to be active and provided a greater alignment of management and shareholder interests.

Three factors were critical to the growth of the US REIT industry in the early 1990s: the existence of a 'credit crunch', the creation of the Umbrella Partnership REIT (UPREIT) structure; and the Omnibus Budget Reconciliation Act 199347. The credit crunch within the

US and global real estate markets of the late 1980s/early 1990s resulted from a combination of overbuilding, the Saving & Loans crisis and foreclosure by lending institutions. Many private companies were forced to consider the equity markets to raise capital, but investors were cautious and demanded increased corporate governance and managerial accountability. In 1992 the introduction of the Umbrella Partners REIT created an additional layer within the REIT structure, which effectively allowed non-REIT real estate companies to swap properties into REITs, consolidating them in the public market whilst deferring any capital gains liabilities. Passed in 1993, this Act changed the ownership structure of REITs. Formerly pension funds had been regarded as single investors but the Act changed the interpretation of pension funds to allow each of the pension investors to be viewed as a separate REIT investor. Pension fund allocations to REITs rebounded as a result.

In the late 1990s, the REIT Simplification Act (REITSA) of 1997, and the REIT Modernization Act (RMA) of 1999 have also made the REIT industry grow rapidly. According to NAREIT data, REITs outperform other leading US benchmark indices including S&P 500, Dow Jones Industry, and NASDAQ Composite in the period of 1975 and 2005. Furthermore, from an international investor's perspective, America has one of the most sophisticated and transparent legal systems when it comes to real estate which gives an investor an extra dimension of confidence in the country as a whole.

(b) United Kingdom

United Kingdom is one of the leading economies in the world and so is the UK property market. The UK property market experienced a boom period in the late 1980s because of the deregulation of financial and property sectors. There were more participants in the industry and investors saw potentially high yields on real estate. However, the market dropped dramatically at the end of 1989 due to the raise of bank base rate and the situation has not become better until 1992. As for securitized real estate sector, the market capitalization was decreasing at 25% per year from 1990 to 1992. In Dec 1992, the market capitalization was 10 billion USD, compared to nearly 17 billion at the beginning of 1990. Starting from 1992, the interest rate fell in order to stimulate investment activity, and hence benefited the property market. By the spring of 1994, the market capitalization reached 25.6 billion USD, significantly recovered from previous losses.

The property market in UK has grown rapidly after the millennium with the increase of foreign investment, especially in real estate industry. In 2001, foreign investment in the UK real estate amounted to GBP 5.7 billion, representing almost 20% of total investment. The US investment in UK real estate dominates, accounting for GBP 2.3 billion or 40%. According to a report from British Property Federation (BPF), as at June 2003, there were 165 indirect investment vehicles invested in UK real estate with a gross asset value of £28.5 billion, a number and value which has grown significantly in a very few years – 26 new funds per annum were launched between 1998 and 2002.

The UK securitized property market recorded continued strong performance after 2004, with the capitalization increased from 40.8 billion USD at the beginning of 2004, to 84.1 billion as at Nov 2006. According to a report from Macquarie Capital Partners, in 2006 the all-property average prime yield was below that of the UK five year swap rate and only 40 basis points higher than the government benchmark yield, reflecting the continued strength of investor interest in UK real estate. Furthermore, the introduction of REITs on 1 January 2007 continues to be a major focus of attention. Many quoted companies have already announced their intention to convert. The industry is now turning its attention to what will happen following the conversion to REIT status of major quoted real estate companies, and the competitive advantage that this brings. Till May 2009 there are 21 REITs successfully listed on London Stock Exchange with sectors in office, retail, industrial and diversified.

(c) Japan

Japan has well established itself as the second largest economy in the world, even after a long-run recession starting from 1989. With the large scale of the whole economy, the high density of population, and the land scarcity, real estate assets always play an important role in Japan. As for the securitized real estate market, there has been a long history of many Japanese real estate companies offering securities under the real estate sub-sector of the stock exchange, such as Mitsui Real Estate Development, Mitsubishi Estate Co., Tokyu Land Co.

Before the recession in 1990s, land and building values increased dramatically with the expansion of the economy, and finally reached the peak in the early 1990s. After property prices arise to peaks, they began to fall drastically. According to Ministry of Construction, in Nov 1991 houses and apartments in metropolitan Tokyo had in the preceding year lost 37% of their value and plots of land in the suburb of Saitama had lost 41%. At the same time, the capitalization of securitized real estate market dropped from a peak of 67.5 billion USD in January of 1990 to 24.2 billion USD in August 1992, losing more than 60% of its value. Since then, the Japanese property market has been in a period of depression.

In 1993, the Japanese prime minister acknowledged that the so called “Bubble Economy” had collapsed. In the second quarter of 1993, Japan’s GDP declined at an annual rate of 2 percent. The real GDP of Japan finally turned upward at the end of 1995, but plunged downward to new depths in 1998. Then, the economic decline continued until 1999, when the real GDP stabilized. During this period, the securitized real estate market in Japan was much more volatile than any other developed economies in the world. The capitalization of real estate assets in Japan has slowly grown from 27.2 billion USD in early 1993, to 42.3 billion in the middle of 1997. Just one year later, it dropped to 17.8 billion USD at November of 1998, because of the impact of Asian financial crisis.

Changes occurred after the financial crisis as foreign investors began purchasing Japanese real estate for the first time. As a dramatic deterioration in real estate prices that lasted for 14 years stopped in 1999, land prices in the country's six largest cities have started to rise once again. In September 2001, Japan introduced REITs, from which a new market emerged and started to expand enormously. Three and a half years after the introduction of REITs, Japanese securitized real estate market has already grown seven times larger then it was. Against the backdrop of recovery in the world's second largest economy, Japan's real estate market is becoming more attractive to foreign investors as a result. It has the potential to grow even larger in the next few years, much of which is credited to REITs.

(d) Hong Kong

The Hong Kong real estate market is buoyant and has already made an excellent investment choice for international buyers; but as the gateway to the largest emerging economy in the world, namely China, Hong Kong is poised on the brink of an incredibly exciting period and this excitement is being felt more and more in the already successful property sector.

In the late 1980s, the property market in Hong Kong began to revive with the highly expanding economic environment and interest rate decline. Until 1997, the Hong Kong real estate market was riding high on the wave of the economic prosperity. Prices were out of reach of average purchasers and to own real estate in Hong Kong you really needed to be high net worth or a corporate investor. The capitalization of the entire securitized real estate sector increased from 12.4billion USD in Jan 1990 to 97.7 billion in the middle of 1997, growing at an annual rate of nearly 35%. In 1997 Hong Kong was handed back by the British to the Chinese. At that time China was not the exciting emerging economy that it is today, rather it was perceived as a restrictive communist country which could potentially cripple the prospects and future prosperity of Hong Kong. As a result of this fear the property sector in Hong Kong received limited investment that year and prices actually began to fall. At the same time, the outburst of the Asian financial crisis also negatively affected Hong Kong economy. Within one year, the capitalization of securitized real estate market in Hong Kong fell from a peak of 97.7 billion USD in the middle of 1997 to 27.3 billion in October 1998. Since then, Hong Kong fell into an extended period of recession.

Six years of recession resulting from the Asian financial crisis, the global recession and then the SARS outbreak meant that Hong Kong's fortunes were severely hampered. Fortunately, with China Mainland's entrance into WTO and CEPA (Closer Economic Partnership Agreement), Hong Kong is expected to integrate further with China and to therefore be in the best position possible to benefit economically from China's booming import and export market. In terms of the real estate market sector this led to a sliding of prices and demand and an overall correction. The capitalization of the securitized real estate market in Hong Kong has now reached 93.6 billion USD in November of 2006, significantly recovered from the recession after Asian financial crisis.

(e) Singapore

The island city-state Republic of Singapore in South East Asia has undergone rapid change and developments in the last few decades. Singapore is an incredibly dynamic little country and one that was ready to diversify when the need presented itself. Its geographic confines have not restricted its output but they have resulted in ever increasing property prices as the continuing success of the business climate in Singapore has resulted in sustained demand for a limited supply of real estate. Singapore has a sophisticated and highly successful free market economy creating vast opportunities for international investors. The property market in Singapore generally consists of the residential, commercial and industrial sub markets. The increasing demand for property in Singapore was being fuelled by the growing vibrancy and attraction of the city.

In the 1970s and 1980s, when the whole economy experienced tremendous growth, the commercial and industrial property developments expanded rapidly as well. From 1990 to 1997, the capitalization of securitized real estate market in Singapore rose from 2.5 billion USD to 26.4 billion, expanding at an average rate of 40% per year. There is a significant boost from the end of 1996 to the middle of 1997, when the whole real estate market almost doubled its size. Being negatively affected by the Asian financial crisis, the market went down after 1997 and the market capitalization declined to only 3.5 billion USD in October 1998. As Singapore economy was highly integrated with the global economy, the securitized real estate market has also gone through several volatile periods after 1998 as the world economy was affected by some significant events such as the 9.11 terrorism attack and the rise of oil price.

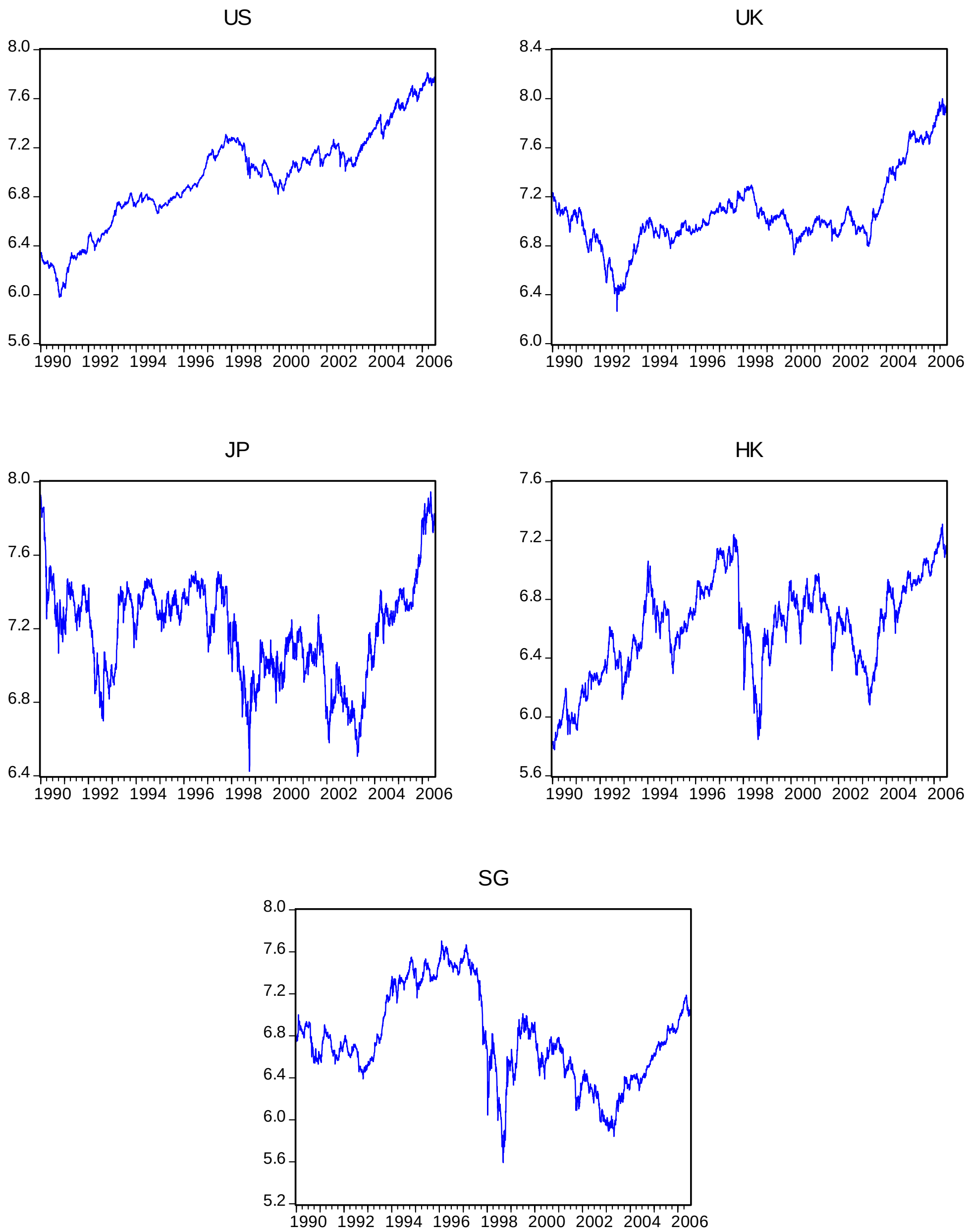
The latest news from the Republic is that Singapore is now in its fifth straight year of economic growth and that the property market in Singapore recorded highest sales in the first half of 2006 - so much that the GDP growth predictions and property market statistics have all had to be positively re-evaluated for 2006 and beyond. Currently property in Singapore as an investment commodity is a successful asset and if the Republic can continue its drive towards economic diversification resulting in growth sustainability, real estate will continue to represent a solid and dependable capital appreciating commodity. The changes to promote sustainable economic stimulus also affect policies governing the foreign ownership of real estate in Singapore which was once very restricted but now been eased. This has led to an increase in demand from overseas investors. The easing of ownership restrictions has also invited property prospectors onto the scene who are developing new residential complexes and targeting the international local community. While interest rates in Singapore remain attractively low, more local demand for property to buy is breaking through.

Finally, a Singapore based REIT may make an attractive investment vehicle for many investors seeking exposure to the Asian property markets as a whole, not just Singapore commercial property. This is because Singapore has made the decision to become the most significant REIT base in Asia, it is currently focused on expanding its market capitalization to USD16 billion by 2007 and there are plans for further expansion into India.

3.3 Price, Return, and Volatility Indices

The raw data used in this study are daily price indices of securitized real estate market in the United States (US), United Kingdom (UK), Japan (JP), Hong Kong (HK), and Singapore (SG) from 1/1/1990 to 6/30/2006. The FTSE / EPRA / NAREIT global real estate indices are collected from DataStream based on US dollar currency for each market. The FTSE / EPRA / NAREIT global real estate indices are designed to track the performance of listed real estate companies and REITs in the world, and are used extensively by investors for investment analysis, performance measurement, asset allocation, portfolio hedging and for creating a wide range of index tracking funds. Figure 3.1 illustrates the price movements in these markets from Jan 1990 to Jun 2006.

Figure 3.1 The Logarithmic Price Indices in International Securitized Real Estate Markets

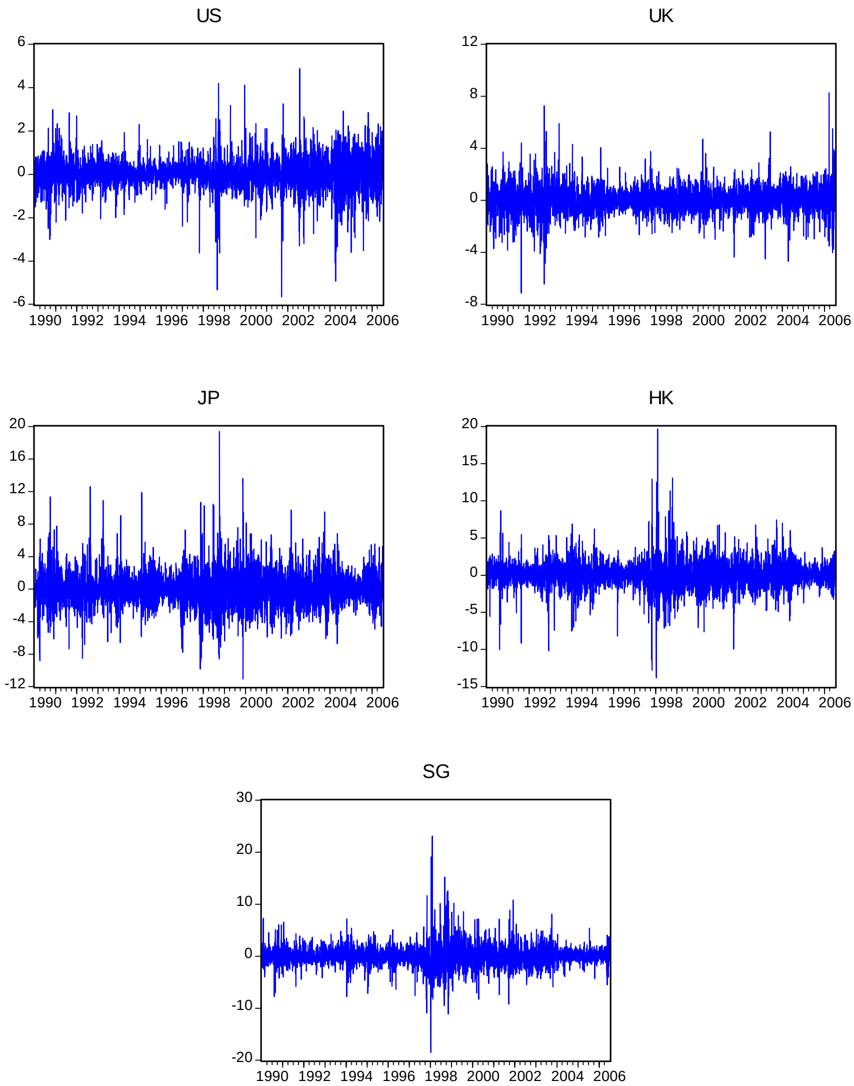


The returns for each securitized real estate market are expressed in percentages computed by multiplying the first difference of the logarithm of property stock market indices by 100.

$$R_{i,t} = 100 \times \left[LN(PI_{i,t}) - LN(PI_{i,t-1}) \right] \qquad t = 1,\ldots,T$$

where i is the securitized market considered (i=US, UK, JP, HK, SG), t the day or week of the sample period. The time series plots of daily returns of the 5 securitized real estate markets are given in Figure 3.2.

Figure 3.2 The Daily Returns in International Securitized Real Estate Markets



The range of the logarithms of the daily price indices over a week is computed to obtain a proxy of the volatility.

$$R'_{i,t} = MAX_{0 \le j \le 5} LN(PI_{i,j,t}) - MIN_{0 \le j \le 5} LN(PI_{i,j,t}), \qquad t = 1,\ldots,T$$

where i is the securitized market considered, t the week and j the day of the week t.

Parkinson (1980) showed that the range, rescaled by an appropriate constant, is an unbiased estimator of the volatility parameter in a diffusion process. In addition, Brunetti and Lildholdt (2002) show that the range is superior to the returns as far as volatility proxies are concerned. Following the results of Brunetti et al. (2003), we have then computed the volatility proxy series for each securitized real estate market:

$$\hat{v}_{i,t} = \sqrt{\pi/8}R'_{i,t}$$

where i is the securitized market considered, t the week of the sample period. Stylized facts suggest that this series is well represented as an ARMA.

Table 3.2 presents descriptive statistics for daily price returns for the whole study period. Sample means, medians, maximums, minimums, standard deviations, skewness, kurtosis, the Jarque-Bara statistic, the Ljung-Box statistics for 6 and 12 lags for returns as well as for squared returns, the Kolmogorov-Smirnov (KS) D-statistics and the ARCH LM test statistics are reported.

Table 3.2 Summary Statistics of Daily Returns

	US	UK	JP	HK	SG
Mean	0.0334	0.0168	-0.0023	0.0314	0.0070
Median	0.0153	0.0000	-0.0664	0.0072	-0.0112
Maximum	4.8760	8.2691	19.3914	19.6752	23.1010
Minimum	-5.6479	-7.1284	-11.0727	-13.8146	-18.4789
Std. Dev.	0.7336	1.0078	2.1669	1.8445	2.0416
Skewness	-0.4143	0.1102	0.5600	0.1747	0.6385
Kurtosis	8.5028	7.7577	7.5180	12.0623	14.9187
Jarque-Bera	5553***	4068***	3885***	14750***	25768***
Normality Test [a]	0.0687***	0.0461***	0.0624***	0.0770***	0.0624***

Ljung-Box statistic for up to 6 and 12 lags					
Q(6) for R_i	138.42***	36.24***	85.76***	59.28***	85.76***
Q(12) for R_i	147.78***	43.77***	94.06***	71.36***	94.06***
Q(6) for R_i^2	642.20***	322.56***	608.34***	759.29***	887.50***
Q(12) for R_i^2	877.15***	381.80***	839.21***	1019.00***	1233.00***
ARCH LM test					
4 lags	91.09***	55.22***	84.50***	97.23***	127.06***
8 lags	51.21***	31.34***	53.66***	61.00***	71.75***
12 lags	35.29***	22.82***	35.98***	47.36***	50.54***

Note:

Data in percentage.

*** Significant at 1% level;

[a] Kolmogorov-Smirnov test for normality.

The average daily returns of all securitized real estate markets are mostly positive and close to zero, ranging from -0.0023% (Japan) to 0.0334% (US). The standard deviations of returns range from 0.7366% (US) to 2.1669% (Japan). The standard deviation results indicate that Asia real estate markets are more volatile than US and UK. Similar evidence can also be found in the constructed volatility series, as the mean level of the volatilities in Asian countries is more than twice of that in US and UK market.

Generally speaking, all the return series appear to be highly non-normal based on further distributional characteristics such as skewness, kurtosis, and Jarque-Bera statistics. In addition, all Kolmogorov-Smirnov test statistics are significant, which leads to a rejection of the assumption of normality of returns for all markets. From the results of Ljung-Box test, we are able to conclude that the squared return series are highly auto-correlated, which indicates the ARCH effects may exist. Moreover, all of the ARCH LM test statistics are significant at the 1% level, reconfirming the existence of ARCH effects in return series. In other words, the nonlinear dependencies in these return series could be due to the presence of conditional heteroskedasticity, which we are trying to filter using the Asymmetric Dynamic Covariance model (a generalized multivariate GARCH model) in Chapter 5.

Table 3.3 Cross-Correlation of Returns and Volatilities of International Securitized Real Estate Markets

Panel A: Return Series

	US	**UK**	**JP**	**HK**	**SG**
US	1.0000	0.1405	0.0618	0.1300	0.1175
UK	0.1405	1.0000	0.1595	0.1577	0.1493
JP	0.0618	0.1595	1.0000	0.2187	0.2187
HK	0.1300	0.1577	0.2187	1.0000	0.4969
SG	0.1175	0.1493	0.2187	0.4969	1.0000

Panel B: Volatility Series

	US	**UK**	**JP**	**HK**	**SG**
US	1.0000	0.1202	0.0747	0.1393	0.0788
UK	0.1202	1.0000	0.0631	0.0592	0.0400
JP	0.0747	0.0631	1.0000	0.2376	0.2218
HK	0.1393	0.0592	0.2376	1.0000	0.5583
SG	0.0788	0.0400	0.2218	0.5583	1.0000

Table 3.3 is the cross-correlation matrix of the securitized real estate market returns and volatility. The correlations of returns range from a high of 0.4969 between Hong Kong and Singapore, to a low of 0.0618 between US and Japan. Meanwhile, the correlations of volatilities range from a high of 0.5583 between Hong Kong and Singapore, to a low of 0.0400 between UK and Singapore. It seems that securitized real estate market in Japan is more correlated with Asian markets. Furthermore, Hong Kong and Singapore are inter-correlated to a large extent in both returns and volatilities, indicating a close relationship between these two Asian economies. In terms of volatility, the correlation coefficients of Asian markets with US and UK are lower than within these Asian markets, suggesting that the volatility transmission is more evident within continents.

3.4 Summary

This chapter introduces the international securitized real estate markets, and describes the corresponding property market indices. It can be summarized as follows:

(a) Instead of direct property market series, securitized real estate market indices are used in this research because the direct property series suffered from several problems such as data frequency and the difficulty of appraisal de-smoothing;

(b) The securitized real estate market has grown rapidly in the last few decades in the world and is now becoming more and more prevalent as a means of investment in real estate industry;

(c) Descriptive statistics demonstrated that Asian securitized real estate markets are more volatile than the US and UK. Moreover, the correlations are stronger within Asian markets. Skewness, kurtosis, JB statistics, D statistics and other distributional test statistics suggest that all daily return series are highly non-normal and serial correlated, which indicate a presence of conditional heteroskedasticity.

Chapter 4

Structural Breaks and Long-Run Relationships

4.1 Introduction

In this chapter, the long-run relationships of international securitized real estate markets are examined. First, in section 4.2 the Bai and Perron (2003) method is used to detect possible structural breaks that may exist in the price and volatility indices of these markets. After that, section 4.3 introduces the stationary test and parametric/non-parametric cointegration test methodologies. The empirical results of long-run relationships of these markets are reported in section 4.4. Finally, section 4.5 concludes.

4.2 Structural Breaks in Securitized Real Estate Markets

Parron (1989) has shown that the existence of a structural break in a series can affect its stationary properties. Both the statistics and econometrics literature contain a vast amount of work on issues related to structural change in time series, most of it specifically designed for the case of a single change. The problem of multiple structural changes has received considerably less but an increasing attention. Related literature includes Andrews et al. (1996), Garcia and Perron (1996), Liu et al. (1997), Lumsdaine and Papell (1997), Morimune and Nakagawa (1997), Bai and Perron (1998, 2003a, 2003b, 2004), among others. Bai and Perron (BP hereafter) considered estimating multiple structural changes in a linear model estimated by least squares. They derived the rate of convergence and the limiting distributions of the estimated break points. The results are obtained under a general framework of partial structural changes which allows a subset of the parameters not to change. They also addressed the important problems of testing for multiple structural changes: a sup Wald type tests for the null hypothesis of no change versus an alternative containing an arbitrary number of changes and a procedure that allows one to test the null hypothesis of, say, l changes, versus the alternative hypothesis of $l+1$ changes. The latter is particularly useful in that it allows a specific to general modeling strategy to consistently determine the appropriate number of changes in the data. This study adopts the Bai and Perron (2003) method to test for possible structural breaks in international securitized real estate markets.

4.2.1 Bai and Perron (2003) Method

The BP method is a new methodology to test for infrequent structural breaks in financial markets. There was also an increasing number of its applications in financial literature. In Monte Carlo experiments, Bai and Perron (2004) find that the BP method is powerful in detecting structural breaks and performs better than earlier methods.

The BP method regress a time series (price index and volatility index in this study) on a constant and test for structural breaks in the constant. Consider such a regression model with m breaks ($m+1$ regimes),

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$$v_{i,t} = \beta_{i,j} + \varepsilon_{i,t}, \qquad t = T_{i,j-1} + 1, ..., T_{i,j} \qquad (4.1)$$

for $j = 1,...,m+1$, where $v_{i,t}$ is the index value for market i at period t. $\beta_{i,j}$ ($j = 1,...,m+1$) is the mean value in regime j. The m-partition ($T_{i,1},...,T_{i,m}$) represents the breakpoints for the different regimes (by convention, $T_{i,0} = 0$, and $T_{i,m+1} = T$). BP treats these breakpoints as unknown, and estimates of the breakpoints are generated using the least squares principle. Now consider estimating Equation (4.1) using least squares: for each m-partition ($T_{i,1},...,T_{i,m}$), the least squares estimates of $\beta_{i,j}$ are generated by minimizing the sum of squared residuals,

$$S_{i,T}(T_{i,1},...,T_{i,m}) = \sum_{k=1}^{m+1} \sum_{t=T_{k-1}+1}^{T_k} (v_{i,t} - \beta_{i,k})^2 \qquad (4.2)$$

Let the regression coefficient estimates based on a given m-partition ($T_{i,1},...,T_{i,m}$), which are denoted by $\hat{\beta}_i(\{T_{i,1},...,T_{i,m}\})$, where $\beta_i = (\beta_{i,1},...,\beta_{i,m+1})'$. Substituting these into Equation (4.2) the estimated breakpoints are given by

$$(\hat{T}_{i,1},...,\hat{T}_{i,m}) = \arg\min_{T_{i,1},...,T_{i,m}} S_{i,T}(T_{i,1},...,T_{i,m}) \qquad (4.3)$$

where the set of admissible m-partition is subject to the set of restrictions given next. It is clear from Equation (4.3) that the breakpoint estimators correspond to the global minimum of the sum of squared residuals objective function. With the breakpoint estimates in hand, it is straightforward to calculate the corresponding least squares regression parameter estimates as

$\hat{\beta}_i = \hat{\beta}_i(\{\hat{T}_{i,1},...,\hat{T}_{i,m}\})$. BP develops an efficient algorithm for the minimization problem in Equation (4.3) based on the principle of dynamic programming.

BP considers testing procedures aimed at identifying the number of structural breaks (m) in Equation (4.1). They begin by specifying a statistic for testing the null hypothesis of no structural breaks against the alternative that there are $m = b$ breaks. Let $(T_{i,1},...,T_{i,b})$ be a partition such that $T_{i,k} = [T\lambda_{i,k}]$ ($k = 1,...,b$). Also define R_i that $(R_i\beta_i)' = (\beta_{i,1} - \beta_{i,2},...,\beta_{i,b} - \beta_{i,b+1})$. BP specifies the following statistic:

$$F_{i,T}(\lambda_{i,1},...,\lambda_{i,b}) = \frac{1}{T}\left(\frac{T-(b+1)}{b}\right)\hat{\beta}_i' R_i' \left[R_i \hat{V}_i(\hat{\beta}_i) R_i'\right]^{-1} R_i \hat{\beta}_i \qquad (4.4)$$

where $\beta_i = (\beta_{i,1},...\beta_{i,b+1})'$ is the vector of regression coefficient estimates, and $\hat{V}_i(\hat{\beta}_i)$ is an estimate of the variance-covariance matrix for $\hat{\beta}_i$ that is robust to heteroskedastic and serial correlation. BP next considers a type of maximum F-statistic corresponding to Equation (4.4),

$$SupF_{i,T}(b) = F_{i,T}(\hat{\lambda}_{i,1},...,\hat{\lambda}_{i,b}), \qquad (4.5)$$

where $\hat{\lambda}_{i,1},...,\hat{\lambda}_{i,b}$ minimize the global sum of squared residuals, $S_{i,T}(T\lambda_{i,1},...,T\lambda_{i,b})$, under the restriction that $(\hat{\lambda}_{i,1},...,\hat{\lambda}_{i,b}) \in \Lambda_{i,\pi}$, where $\Lambda_{i,\pi} = \left\{(\lambda_{i,1},...,\lambda_{i,b}); \left|\lambda_{i,k+1} - \lambda_{i,k}\right| \geq \pi, \lambda_{i,1} \geq \pi, \lambda_{i,b} \leq 1-\pi\right\}$ for some arbitrary positive number π (the trimming parameter).

BP develops two statistics, what they call the “double maximum” statistics, for testing the null hypothesis of no structural breaks against the alternative hypothesis of an unknown number of breaks given an upper bound M. The first double maximum statistic is given by

$$UD\max = \max_{1\le m\le M} SupF_{i,T}(m), \qquad (4.6)$$

The second double maximum statistic applies different weights to the individual tests such that the marginal p-values are equal across values of m and is denoted $WD\max$ (see Bai and Perron 1998, p. 59 for details).

Finally, BP proposes a test for the null hypothesis of l breaks against the alternative hypothesis of $l+1$ breaks. It begins with the global minimized sum of squared residuals for a model with l breaks. Each of the intervals defined by the l breaks is then analyzed for an additional structural break. From all of the intervals, the partition allowing for an additional break that results in the largest reduction in the sum of squared residuals is treated as the model with $l+1$ breaks. The $SupF_{i,T}(l+1|l)$ statistic is used to test whether the additional break leads to a significant reduction in the sum of squared residuals. BP derives asymptotic distributions for the double maximum and $SupF_{i,T}(l+1|l)$ statistics, and provide critical values for various values of π and M.

A prominent feature of the BP method, compared to other structural break tests, is that it allows for general specifications when computing test statistics and confidence intervals for the break dates and regression coefficients. These specifications include autocorrelation and heteroskedasticity in the regression model residuals, as well as different moment matrices for the regressors in the different regimes. The most general BP specification is used in this study to allow for all of these features. These conditions are general when no lagged dependent variables are included in Equation (4.1). These conditions are sufficient to capture the most common features of volatility.

BP has also discussed a sequential application of the $SupF_{i,T}(l+1|l)$ statistics – a specific-to-general modeling strategy – as a way to determine the number of structural breaks. Although BP finds that this procedure performs well in some settings, its performance can be improved when multiple breaks are present, as the $SupF_{i,T}(1|0)$ statistic can have low power in the presence of multiple breaks. On the basis of extension Monte Carlo simulations, BP recommends the following strategy to identify the number of breaks. First, examine the double maximum statistics to determine whether any structural breaks are present. If the double maximum statistics are significant, examine the $SupF_{i,T}(l+1|l)$ statistics to decide on the number of breaks, choosing the $SupF_{i,T}(l+1|l)$ statistic that rejects for the largest value of l.

4.2.2 Results of Structural Breaks

Table 4.1 reports BP statistics for tests of structural change in the price indices and the constructed volatility indices. For all securitized real estate markets, both double maximum statistics ($UD\max$ and $WD\max$) are highly significant, which provides strong evidence of structural change in prices and volatilities during the sample period.

Table 4.1 Bai and Perron Tests of Multiple Structural Breaks for Securitized Real Estate Markets

Panel A: Price Index							
Series	**UDmax**[a]	**WDmax**[b]	**SupF(2|1)**[d]	**SupF(3|2)**[e]	**SupF(4|3)**[f]	**SupF(5|4)**[g]	**Breaks**
US	16.24***	21.33***	6.13	3.38	0.29	—	1
UK	10.26***	10.26***	0.97	0.21	0.12	0.05	1
JP	14.98***	29.74***	2.56	0.85	0.85	—	1
HK	10.60***	15.36***	1.62	1.28	0.29	0.27	1
SG	24.97***	49.57***	4.09	0.24	4.56	—	1
Panel B: Volatility Index							
Series	**UDmax**[a]	**WDmax**[b]	**SupF(2|1)**[d]	**SupF(3|2)**[e]	**SupF(4|3)**[f]	**SupF(5|4)**[g]	**Breaks**
US	62.55***	86.66***	21.87***	23.17***	0.97	—	3
UK	29.39***	29.39***	10.84**	3.65	2.37	—	2
JP	13.72***	26.73***	19.80***	12.89**	12.89**	0.48	4
HK	15.19***	33.59***	27.22***	20.93***	8.5	10.66*	3
SG	88.62***	88.62***	44.70***	98.47***	4.17	—	3

Note:

The double maximum statistics (UDmax and WDmax) are highly significant, indicating that there is at least one structural break in the time series. The number of breaks are decided by examining the $SupF_{i,T}(l+1|l)$ statistics, choosing the $SupF_{i,T}(l+1|l)$ statistic that rejects for the largest value of l.

[a]One-sided (upper-tail) test of the null hypothesis of 0 breaks against the alternative hypothesis of an unknown number of breaks given an upper bound of 5; 10%, 5%, and 1% critical values equal 7.46, 8.88, and 12.37, respectively.

[b]One-sided (upper-tail) test of the null hypothesis of 0 breaks against the alternative hypothesis of an unknown number of breaks given an upper bound of 5; critical value equals 13.83.

[c]One-sided (upper-tail) test of the null hypothesis of 0 breaks against the alternative hypothesis of 1 break; 10%, 5%, and 1% critical values equal 7.04, 8.58, and 12.29, respectively.

[d]One-sided (upper-tail) test of the null hypothesis of 1 break against the alternative hypothesis of 2 breaks; 10%, 5%, and 1% critical values equal 8.51, 10.13, and 13.89, respectively.

[e]One-sided (upper-tail) test of the null hypothesis of 2 breaks against the alternative hypothesis of 3 breaks; 10%, 5%, and 1% critical values equal 9.41, 11.14, and 14.80, respectively.

[f]One-sided (upper-tail) test of the null hypothesis of 3 breaks against the alternative hypothesis of 4 breaks; 10%, 5%, and 1% critical values equal 10.04, 11.83, and 15.28, respectively.

[g]One-sided (upper-tail) test of the null hypothesis of 4 breaks against the alternative hypothesis of 5 breaks; 10%, 5%, and 1% critical values equal 10.58, 12.25, and 15.76, respectively.

*** Significant at the 1% level; ** Significant at the 5% level. * Significant at the 10% level.

$SupF_{i,T}(l+1|l)$ tests are performed to further determine the number of structural breaks. For price indices, none of the sequential tests is significant, indicating no evidence of more than one break in the prices. However, volatility indices exhibit clear evidence of multiple structural breaks. For US, Hong Kong and Singapore, both $SupF_{i,T}(2|1)$ and $SupF_{i,T}(3|2)$ are significant, whereas $SupF_{i,T}(4|3)$ and $SupF_{i,T}(5|4)$ are not significant. This suggests that there are three structural breaks (four regimes) in the volatility series of each country. Similarly, four breaks are detected in the volatility series in Japan and two breaks are found in UK.

Table 4.2 reports the dates for the structural breaks in both price and volatility series and their 90% and 95% confidence intervals for each of the break dates. For prices indices, only one break point is detected in each market. UK has a structural break at the end of 2003, whereas all other markets have structural breaks around 1996 to 1997, which coincide with the outburst of the Asian financial crisis and the internet and high-tech bubble in the United States. On the other hand, multiple structural breaks are found in volatility series. For example, three breaks are detected in US: Apr 15, 1994, Jun 5, 1998, and Jan 9, 2004. The 90% and 95% confidence intervals for the break dates are reported below the break dates. These range between one and two years of the estimated break date.

This chapter mainly focuses on the stationarity and long-run cointegration relationships of the price indices. The multiple structural breaks in volatilities and the corresponding influences on market return and volatility characteristics will be discussed in Chapter 5.

Table 4.2 Bai and Perron Break Dates, and 90% and 95% Confidence Intervals for Price and Volatility in Securitized Real Estate Markets

Series	Break 1	Break 2	Break 3	Break 4
		Panel A: Price Index		
US	9/2/96			
90% CI	[7/18/95-12/19/96]			
95% CI	[2/16/95-5/21/97]			
UK	12/22/03			
90% CI	[4/3/03-11/21/04]			
95% CI	[9/17/02-9/16/05]			
JP	11/7/97			
90% CI	[6/3/97-1/6/98]			
95% CI	[12/19/96-6/24/98]			
HK	11/6/97			
90% CI	[4/3/97-2/12/98]			
95% CI	[10/22/96-7/23/98]			
SG	10/12/97			
90% CI	[5/5/97-1/13/98]			
95% CI	[10/7/96-5/19/98]			
		Panel B: Volatility Index		
US	4/15/94	6/5/98	1/9/04	—
90% CI	[11/19/93,6/2/95]	[10/3/97,8/21/98]	[7/4/03,5/27/05]	—
95% CI	[9/10/93,11/10/95]	[6/13/97,9/11/98]	[3/28/03,12/9/05]	—
UK	10/8/93	3/7/03	—	—
90% CI	[6/18/93,6/3/94]	[2/16/01,4/2/04]	—	—
95% CI	[4/30/93,9/9/94]	[4/14/00,10/8/04]	—	—
JP	9/11/92	10/17/97	4/21/00	11/14/03
90% CI	[6/26/92,1/14/94]	[3/21/97,11/21/97]	[2/25/00,3/30/01]	[1/10/03,11/12/04]
95% CI	[5/8/92,7/22/94]	[12/27/96,12/5/97]	[1/21/00,08/10/01]	[8/30/02,4/8/05]
HK	6/6/97	1/7/00	11/28/03	—
90% CI	[8/9/96,8/1/97]	[10/8/99,9/28/01]	[7/25/03,10/15/04]	—
95% CI	[4/5/96,9/5/97]	[8/6/99,6/7/02]	[5/23/03,2/25/05]	—
SG	8/22/97	2/11/00	10/24/03	—
90% CI	[2/14/97,8/29/97]	[1/28/00,1/5/01]	[10/3/03,1/9/04]	—
95% CI	[12/6/96,9/5/97]	[1/21/00,5/11/01]	[9/19/03,2/13/04]	—

Note:

The first number in each cell is the break date estimated by the BP method;

90% and 95% confidence intervals (CI) for the end dates are reported in brackets.

4.3 Stationary Tests and Cointegration Tests

This section introduces the methodologies for testing stationarity and long-run cointegration relationships in time series, including unit root test, Johansen's cointegration test, and two non-parametric cointegration tests (Bierens, 1997; Breitung, 2002).

4.3.1 Stationary (Unit Root) tests for individual time series

As discussed in Engle and Granger (1987), a series is said to be integrated of order d （$I(d)$） if it is nonstationary, but when differenced d times, it has a stationary, invertible, ARMA representation. A system consisting of two or more series is said to be cointegrated if the individual time series comprising the system are integrated of order one, but have a linear combination that is stationary (or integrated of order zero). Unit root tests are used to identify the integration order of a time series.

An important assumption of the DF (Dickey-Fuller) test is that the error terms are independently and identically distributed. The ADF (Augmented Dickey-Fuller) test adjusts the DF test to take care of possible serial correlation in the error terms by adding the lagged difference terms of the regressand. The ADF test for stationarity of a time series, Y_t, begins with the estimation of the following regression equation when no linear trend is considered:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \sum_{j=1}^{p} \gamma_i \Delta Y_{t-j} + \varepsilon_t \qquad (4.7)$$

When a linear trend is considered (4.7) becomes as follows:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{j=1}^{p} \gamma_i \Delta Y_{t-j} + \varepsilon_t \qquad (4.8)$$

If $\alpha_1 = 0$, then the series is said to have a unit root and is nonstationary. Hence, if the hypotheses, $\alpha_1 = 0$, is rejected for one of the above two equations it can be concluded that the time series does not have a unit root and is stationary (integrated of order zero). The parameters α_0 and α_2 are to test for the presence of drift and trend components, respectively, in the time series. However, it is pertinent to note that the distributions of the ordinary t- and F-statistics computed for the regressions do not have the expected distributions. Therefore, the critical values for testing various hypotheses have been estimated using Monte Carlo simulations by Davidson and MacKinnon (1993).

An alternative to the ADF test is the PP (Phillips-Perron) test. Phillips and Perron use nonparametric statistical methods to take care of the serial correlation in the error terms without adding lagged difference terms. Specifically, the PP test corrects the standard errors of the t-values using the Newly and West (1987) correction, rather than including the lagged values of ΔY_t as independent variables.

4.3.2 Johansen Cointegration Test

Once the unit root tests are completed, we can proceed to test for cointegration for different groups. A powerful test for determining cointegrating relationships in time series systems was introduced by Johansen (1988). The description that follows draws heavily from Johansen (1988, 1991, 1994) and Johansen and Juselius (1990, 1991). The Johansen methodology presents some distinct advantages compared to earlier residual-based tests. For example, identification of the number of cointegrating vectors is possible with the Johansen test.

To check for stationarity arising from a linear combination of variables, the following AR representation for a vector Y_t made up of n variables is used,

$$Y_t = c + \sum_{i=1}^{s-1} \phi_i Q_{it} + \sum_{i=1}^{k} \pi_i Y_{t-i} + \varepsilon_t$$

where Y is at most $I(1)$, Q_{it} are seasonal dummies (i.e., a vector of non-stachastic variables) and c is a constant. If an error-correction term is appended, this becomes:

$$Y_t = c + \sum_{i=1}^{s-1} \phi_i Q_{it} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \prod Y_{t-k} + \varepsilon_t$$

which is basically a vector representation of Equation (4.7) with seasonal dummies added. All long-run information is contained in the levels term $\prod Y_{t-k}$ and the short-run information in the differences ΔY_{t-i}. The above equation would have the same degree of integration on both sides only if $\Pi = 0$ (the series are not cointegrated) or ΠY_{t-k} is $I(0)$, which infers cointegration. In order to test for cointegration, the validity of $H_1(r)$, shown below, is tested:

$$H_1(r) : \Pi = \alpha\beta',$$

Where β is a matrix of cointegration vectors and α represents a matrix of error correction coefficients. The hypothesis $H_1(r)$ implies that the process ΔY_t is stationary, Y_t is nonstationary and $\beta' Y_t$ is stationary (Johansen, 1991). The Johansen method yields the Trace and the $L_{\max}$ statistics that enable determination of the number of cointegrating vectors.

4.3.3 Non-parametric Cointegration Test

It has been noted that the traditional estimators for cointegration processes rely on either parametric specifications of short-run dynamics or kernel type estimators of nuisance parameters implied by the short-run dynamics of the process (Breitung, 2002; Bierens, 1997). Examples of these approaches include Phillips and Perron (1988) and Quintos (1998) for kernel estimation and the Johansen type approaches for the autoregressive representation. However, if these parametric representations fail to capture the specific features of the time series, say the nonlinearity, traditional cointegration tests will probably lead to erroneous conclusions. Therefore, given that people still do not fully understand the statistical characteristics of prices, it is quite necessary to carry out non-parametric cointegration tests for price series as complements.

(a) Bierens's (1997) Method

The Bierens's non-parametric cointegration test considers the general framework as:

$$z_t = \pi_0 + \pi_1 t + y_t$$

where $\pi_0 (q \times 1)$ and $\pi_1 (q \times 1)$ are optimal mean and trend terms, and y_t is a zero-mean unobservable process such that Δy_t is stationary and ergodic. The general framework assumes that z_t is observable q-variate process for $t = 0, 1, 2, ..., n$.

Apart from some mild regularity conditions, or estimation of structural and/or nuisance parameters, further specification of the data-generating process for z_t are not required and thus this test is completely non-parametric.

The Bierens's method is based on the generalized eigenvalues of matrices A_m and $(B_m + n^{-2} A_m^{-1})$, where A_m and B_m are defined in the following matrices:

$$A_m = \frac{8\pi^2}{n} \sum_{k=1}^{m} k^2 \left(\frac{1}{n} \sum_{t=1}^{n} \cos(2k\pi(t-0.5)/n) z_t \right) \left(\frac{1}{n} \sum_{t=1}^{n} \cos(2k\pi(t-0.5)/n) z_t \right)'$$

$$B_m = 2n \sum_{k=1}^{m} \left(\frac{1}{n} \sum_{t=1}^{n} \cos(2k\pi(t-0.5)/n) \Delta z_t \right) \left(\frac{1}{n} \sum_{t=1}^{n} \cos(2k\pi(t-0.5)/n) \Delta z_t \right)'$$

which are computed as sums of outer-products of weighted means of z_t and Δz_t, and n is the sample size. To ensure invariance of the test statistics to drift terms, the weight functions of $\cos(2k\pi(t-0.5)/n)$ are recommended here.

Similar to the properties of the Johansen and Juselius likelihood ratio method, the ordered generalized eigenvalues of this non-parametric method are obtained as solution to the problem $\det[P_n - \lambda Q_n] = 0$ when the pair of random matrices $P_n = A_m$ and $Q_n = (B_m + n^{-2} A_m^{-1})$ are defined. Thus, it can be used to test hypothesis on the cointegration rank r.

To estimate r, two test statistics are used. First, Bierens derives the 'lambda-min'($\lambda_{\min}$), $\hat{\lambda}_{n-r_0,m}$, which corresponds to the Johansen's maximum likelihood procedure, to test for the hypothesis of $H_0(r)$ against $H_1(r+1)$. The critical values for this test are tabulated in the same article. Second, Bierens's approach also provides the $g_m(r)$, which is computed from the Bierens's generalized eigenvalues:

$$\begin{aligned}
\hat{g}_m(r) &= \left(\prod_{k=1}^{q} \hat{\lambda}_{k,m}\right)^{-1} && \text{if } r=0 \\
&= \left(\prod_{k=1}^{q-r} \hat{\lambda}_{k,m}\right)^{-1} \left(n^{2r} \prod_{k=n-r+1}^{q} \hat{\lambda}_{k,m}\right) && \text{if } r=1,...,n\text{-}1 \\
&= n^{2n} \prod_{k=1}^{q} \hat{\lambda}_{k,m} && \text{if } r=n
\end{aligned}$$

This statistic uses the tabulated optimal values (see Bierens, 1997, Table 1) for r, provided $r > q$, and $m = q$ is chosen when $r = n$. Then $\hat{g}_m(r)$ converges in probability to infinity if the true number of cointegrating vector is unequal to r, and $\hat{g}_m(r) = O_p(1)$ if the true number of cointegrating vector is equal to r. Therefore, we have $\lim_{n\to\infty} P(\hat{r}_m = r) = 1$, when $\hat{r}_m = \arg \min_{0 \le r \le 1} \{\hat{g}_m(r)\}$. Thus, this test statistic is useful as a tool to double-check on the determination of r.

Finally, a linear restriction on the cointegrating vectors is needed because not all of the series will enter the cointegrating vector system. To address this issue, Bierens proposes the trace and lambda-max statistics. The critical values of trace and lambda-max tests are given in Bierens (1997, Table 3 and 4).

(b) Breitung's (2002) Method

Breitung has suggested another non-parametric procedure for the test of cointegration. Let Y_t be a process

$$Y_t = \delta' d_t + x_t$$

where d_t is the deterministic part, and x_t the stochastic part. The deterministic component d_t may include constant, time trend or dummy variables. The stochastic part of the series, x_t, is decomposed as a random walk and a transitory component that represents a short-run dynamics of the process. Breitung first suggests a variance ratio test statistic for a unit root, similar to the one of Kwiatkowski et al. (1992). Breitung's variance ratio test statistic is employed for testing the null hypothesis that $Y_t \sim I(1)$ against the alternative $Y_t \sim I(0)$. The test statistic constructed as

$$\hat{\rho}_T = \frac{T^{-1}\sum_{t=1}^{T}\hat{U}_t^2}{\sum_{t=1}^{T}\hat{u}_t^2}$$

where $\hat{u}_t = Y_t - \hat{\delta}' d_t$ and $\hat{U}_t = \sum_{i=1}^{t}\hat{u}_i$. The limiting distribution of the test statistic is

$$T^{-1}\hat{\rho}_T = \frac{T^{-4}\sum_{t=1}^{T}\hat{U}_t^2}{T^{-2}\sum_{t=1}^{T}\hat{u}_t^2} \Rightarrow \frac{\int_0^1\left[\int_0^a \tilde{W}_j(s)ds\right]^2}{\int_0^1 \tilde{W}_j(a)^2 da}$$

Breitung provides simulated critical values of the asymptotic distribution under the null hypothesis. Breitung next generalises variance ratio statistic for a nonparametric unit root to test hypotheses on cointegrating rank. It is assumed that the process can be decomposed into a q-dimensional vector of stochastic components ξ_t and $(n-q)$-dimensional vector of transitory components υ_t. The dimension of the stochastic component is related to the cointegration rank of the linear system by $q = (n-r)$, where r is the rank of the matrix Π in the vector-error correction representation of the process $\Delta Y_t = \Pi Y_{t-1} + e_t$. The test statistic for cointegration rank is based on the eigenvalues $\lambda_j \, (j = 1, \ldots, n)$ of the problem

$$\left|\lambda_j B_T - A_t\right| = 0$$

where $A_T = \sum_{t=1}^{T} \hat{u}_t \hat{u}_t'$, $B_T = \sum_{t=1}^{T} \hat{U}_t \hat{U}_t'$ and $\hat{U}_t = \sum_{i=1}^{t} \hat{u}_i$. The eigenvalues of (11) can be found by finding the eigenvalues of the matrix $R_T = A_T B_T^{-1}$. The eigenvalues of (11) can be written as

$$\lambda_j = \frac{(\eta_j' A_T \eta_j')}{(\eta_j' B_T \eta')}$$

where η_j is the eigenvector associated with the eigenvalue λ_j. The test statistic for the hypothesis that $r = r_0$ is given by

$$\Lambda_q = T^2 \sum_{j=1}^{q} \lambda_j$$

where $\lambda_i \leq \lambda_2 \leq \lambda_3 \leq \cdots \leq \lambda_n$, is the series of ordered eigenvalues of the matrix R_T.

4.4 Empirical Results of Stationarity and Cointegration

4.4.1 Stationarity and linear structure

Table 4.3 presents the ADF and PP results for daily price index series of each securitized real estate market. The number of lags is determined by Akaike information criteria (AIC). To check for nonstationarity in the level series, the hypothesis of $\alpha_1 = 0$ in Equation (4.7) and

Equation (4.8) is examined. The results are not surprising and consistent with other studies. Both the ADF and PP method do not reject the null hypothesis of non-stationarity in the level series with or without trend. However, the first differences of these level series are all stationary, according to both tests. In other words, the price indices in these securitized real estate markets are integrated of order 1 ($I(1)$), clearly suggesting the possibility of the existence of cointegration among these series.

Table 4.3 Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Tests of Stationarity for Price Indices

Series		**ADF Test**		**PP Test**	
		No Trend $\alpha_1 = 0$	**Trend** $\alpha_1 = 0$	**No Trend** $\alpha_1 = 0$	**Trend** $\alpha_1 = 0$
US	Level	-0.17	-1.77	-0.12	-1.71
	First diff.	-40.62**	-40.62**	-55.75**	-55.75**
UK	Level	0.59	-1.36	0.43	-1.48
	First diff.	-60.36**	-60.45**	-60.68**	-60.70**
JP	Level	-2.72	-2.47	-2.83	-2.58
	First diff.	-31.25**	-31.30**	-58.49**	-58.53**
HK	Level	-2.49	-2.81	-2.49	-2.79
	First diff.	-11.43**	-11.43**	-59.01**	-59.01**
SG	Level	-1.66	-1.67	-1.66	-1.67
	First diff.	-13.72**	-13.72**	-58.33**	-58.33**

Note:
** Significant at 5% level;
Both ADF and PP tests are computed with and without linear trend. If the hypothesis $\alpha_1 = 0$ cannot be rejected, then the series is said to have a unit root and is nonstationary. The number of lags is determined by a test of significance such as the AIC.

To further determine the linear structure of these securitized real estate price indices, an F-test is carried out to test for the presence of drift and trend in Equation (4.7) and Equation (4.8). Specifically, if the series has a unit root (i.e., $\alpha_1 = 0$) and the F-statistic of $\alpha_0 = \alpha_1 = 0$ in Equation (4.7) is not significant, this suggests the presence of the constant term or drift in the series. Overall, the results in Table 4.4 suggest the presence of drift in all series. If the series has a unit root and the F-statistic of $\alpha_1 = \alpha_2 = 0$ is not significant, this denotes presence of trend and suggests that the model with trend is probably more appropriate for the series. Table 4.4 shows that the model with trend is appropriate in most instances. Thus, a model that includes a term of constant and trend is necessary in the linear parametric investigations, such as the Johansen cointegration test.

Table 4.4 Tests of the Presence of Linear Drift and Trend in Price Indices

	No Trend	Trend	
Series	$\alpha_0 = \alpha_1 = 0$	$\alpha_0 = \alpha_1 = \alpha_2 = 0$	$\alpha_1 = \alpha_2 = 0$
US	2.99	3.13	1.72
UK	0.71	3.07	4.07
JP	3.69	2.46	3.69
HK	3.56	2.97	4.00
SG	1.40	0.97	1.43
Critical Value			
10%	3.78	4.03	5.34
5%	4.59	4.68	6.25

Note:

The F-statistics are computed to test the parameters α_0 and α_2 to verify the presence of drift and trend. Asymptotic critical values are from Davidson and MacKinnon (1993).

4.4.2 Johansen Cointegration Results

Many factors favor cointegration among real estate assets. It is well accepted that common macroeconomic fundamentals will produce comovements in prices. Other factors, such as falling mortgage rates and increasing population levels, may also influence cointegration (see Chaudhry et al, 1999). On the other hand, shifting demographics, differences in legislation across regions, and the lead-lag effects of economic forces across state and regional economies, will reduce the level of cointegration (see Fisher and Webb, 1992; Chaudhry et al, 1999).

The results of Johansen cointegration test are presented in Table 4.5. Two tests, the Trace statistic and the maximum eigenvalue ($L_{\max}$) statistic, are reported. These are basically likelihood ratio tests where the null hypothesis is $L_{r+1} = L_{r+2} = \cdots = L_p = 0$, indicating that the system has $p - r$ unit roots, where r is the number of cointegrating vectors. The rank is then determined using a sequential approach starting with the hypothesis of p unit roots. If this is rejected then the next hypothesis $L_2 = L_3 = \cdots = L_p = 0$ is tested and so on. The optimum number of lags is determined by the likelihood ratio test which selects the minimum lag providing diagnostic results that returned uncorrelated residuals. Manning (2002) discussed this issue in relation to using stock index prices. The results in Table 4.5 suggest the rejection of the hypothesis of no cointegration ($r = 0$) for the full sample period according to both Trace and Eigenvalue statistic.

To further examine the cointegration structure over time and to incorporate the possible effect of a structural break, the full sample period is divided into three sub sample periods according to the break dates specified in Table 4.2.

For the first sub period from 1/1/1990 to 9/2/1996, both Trace statistic and $L_{\max}$ statistic fail to reject the hypothesis of no cointegration ($r = 0$). Whereas for the second and third sub periods, both test statistics indicate a cointegration rank of 1, indicating that there are common factors binding the price series in these periods. It is also noteworthy that the Trace statistic and $L_{\max}$ statistic values are growing over time. For example, for $r = 0$, the Trace statistic in the first period is 84.34, and it grows to102.68 in the second sub period and 118.01 in the third sub period.

Table 4.5 The Johansen Tests for Cointegration in International Securitized Real Estate Markets

H_0	**Trace**	**CV(5%)**	$\lambda_{\max}$	**CV(5%)**
Panel A: Full period: 1/1/1990 to 6/30/2006				
$r \le 0$	83.90	88.80	32.37	38.33
$r \le 1$	51.53	63.88	22.62	32.12
$r \le 2$	28.91	42.92	17.41	25.82
$r \le 3$	11.51	25.87	8.10	19.39
$r \le 4$	3.41	12.52	3.41	12.52
Panel B: First sub period: 1/1/1990 to 9/2/1996				
$r \le 0$	84.34	88.80	27.57	38.33
$r \le 1$	56.77	63.88	22.23	32.12
$r \le 2$	34.54	42.92	17.10	25.82
$r \le 3$	17.44	25.87	11.56	19.39
$r \le 4$	5.88	12.52	5.88	12.52
Panel C: Second sub period: 11/7/1997 to 12/22/2003				
$r \le 0$	102.68**	88.80	39.37**	38.33
$r \le 1$	63.31	63.88	26.84	32.12
$r \le 2$	36.48	42.92	17.51	25.82
$r \le 3$	18.97	25.87	11.94	19.39
$r \le 4$	7.03	12.52	7.03	12.52
Panel C: Third sub period: 12/23/2003 to 6/30/2006				
$r \le 0$	118.01**	88.80	61.73**	38.33
$r \le 1$	56.28	63.88	20.74	32.12
$r \le 2$	35.54	42.92	16.43	25.82
$r \le 3$	19.11	25.87	12.95	19.39
$r \le 4$	1.88	9.16	1.88	9.16

Note:

** Significant at 5% level;

The optimum number of lags is determined by the likelihood ratio test statistics.

Table 4.6 Johansen's Test of Restriction on Each Market

Hypothesis	Time Period			
	1/1/1990 to 6/30/2006	**1/1/1990 to 9/2/1996**	**11/7/1997 to 12/22/2003**	**12/23/2003 to 6/30/2006**
$\beta^{US}=0$	—	—	14.85**	1.63
$\beta^{UK}=0$	—	—	10.45**	0.38
$\beta^{JP}=0$	—	—	9.58**	4.67**
$\beta^{HK}=0$	—	—	8.12**	5.40**
$\beta^{SG}=0$	—	—	6.75**	14.07**

Note:

** Significant at 5% level;

Although cointegration exists in these markets for the last two sub periods, not all of them will enter the cointegrating vector system. To address this issue, the LR test of restriction on each of the cointegrating parameter is performed. The results are presented in Table 4.6. For the sub period of 11/7/1997 to 12/22/2003, the LR statistics in all countries reject the null hypothesis that the cointegrating parameter equal to zero. For the last sub period, however, the securitized real estate markets in US and UK seem weakly 'exogenous' with respect to β.

The results of Johansen cointegration test suggest much stronger binding in international securitized real estate markets after 1997. Possible explanations include the increasing globalization of the financial markets, the increase of the international capital flow movements, and the rapid growth of the securitized real estate markets that has been seen after 1998. Other issues, such as deregulation of local real estate investment in most countries, may have also played a role.

4.4.3 Non-parametric Cointegration Results

Table 4.7 Bierens's Non-parametric Cointegration Test Results ($\lambda_{\min}$ statistics)

Hypothesis		Time Period			
H_0	H_1	**1/1/1990 to 6/30/2006**	**1/1/1990 to 9/2/1996**	**11/7/1997 to 12/22/2003**	**12/23/2003 to 6/30/2006**
$r=0$	$r=1$	0.00002**	0.00468	0.00001**	0.00000**
$r=1$	$r=2$	0.05546	0.00971	0.00046**	0.02052
$r=2$	$r=3$	0.23482	0.39825	0.40645	0.06983
$r=3$	$r=4$	2.43990	0.71221	4.39705	0.71854
$r=4$	$r=5$	8.43179	5.39299	23.19867	1.29320
Result		**1 CE**	**0 CE**	**2 CE**	**1 CE**

Note:

** Significant at 5% level;

CE refers to Cointegration Equation.

The Bierens's (1997) non-parametric cointegration results are presented in Table 4.7 and Table 4.8. The method uses both the $\lambda_{\min}$ and $g_m(r_0)$ statistics to determine the cointegration rank r. The results from Table 4.7 show that the $\lambda_{\min}$ statistic is able to reject the null hypothesis of $r=0$ for the full sample period, but not for the case when the null hypothesis is $r=1$. This implies that there exists at most one cointegrating vector among the five securitized real estate markets. This finding is further supported by the $g_m(r_0)$ statistic given in Table 4.8, in which the smallest value (1.45×10^3) appears in the cointegration rank of $r=1$.

The lambda-max statistics are reported to test of restriction on each of the cointegrating parameter. The results in Table 4.9 clearly indicate that except for UK, all other statistics reported are able to reject the null hypothesis that the cointegrating parameter equal to zero, at the conventional 5% level of significance. Thus, it can be concluded that there exist cointegration relationships in these markets, but UK is less ‘endogenous’ than the other four markets.

Table 4.8 Bierens's Non-parametric Cointegration Test Results ($g_m(r_0)$ statistics)

Cointegration Rank (r)	Time Period			
	1/1/1990 to 6/30/2006	1/1/1990 to 9/2/1996	11/7/1997 to 12/22/2003	12/23/2003 to 6/30/2006
$r_0 = 0$	1.78×10^{5}	1.26×10^{3} **	4.22×10^{6}	1.36×10^{9}
$r_0 = 1$	1.45×10^{3} **	2.04×10^{6}	1.65×10^{3}	1.79×10^{2} **
$r_0 = 2$	8.25×10^{7}	3.64×10^{10}	8.96×10^{2} **	3.27×10^{4}
$r_0 = 3$	8.42×10^{13}	1.33×10^{16}	3.78×10^{8}	6.90×10^{7}
$r_0 = 4$	9.29×10^{21}	5.61×10^{22}	1.86×10^{16}	1.54×10^{13}
$r_0 = 5$	1.22×10^{31}	5.98×10^{29}	2.56×10^{25}	1.12×10^{19}
Result	**1 CE**	**0 CE**	**2 CE**	**1 CE**

Note:

** denotes the minimum test statistics;

CE refers to Cointegration Equation.

Table 4.9 Bierens's Test of Restriction on Each Market

Hypothesis	Time Period			
	1/1/1990 to 6/30/2006	1/1/1990 to 9/2/1996	11/7/1997 to 12/22/2003	12/23/2003 to 6/30/2006
$\beta^{US} = 0$	19.68**	—	11.39**	1.73
$\beta^{UK} = 0$	2.93	—	9.33**	1.13
$\beta^{JP} = 0$	4.21**	—	6.74**	1.09
$\beta^{HK} = 0$	7.44**	—	14.64**	7.37**
$\beta^{SG} = 0$	16.37**	—	9.51**	5.72**
Critical Value:				
5%	4.08	—	2.85	4.08
10%	3.13	—	2.31	3.13

Note:

** Significant at 5% level;

For the first sub period, 1/1/1990 to 9/2/1996, no cointegration relationship is found according to both $\lambda_{\min}$ and $g_m(r_0)$ statistics. However, significant cointegration vectors are found in the next two sub periods, indicating that the international securitized real estate markets are more correlated and have long-run relationship after 1997. In addition, two test statistics give the same results on cointegration ranks. From the restriction test in Table 4.9, all the five securitized real estate markets belong to the cointegrating system for the time period of 11/7/1997 to 12/22/2003. However, for the time period of 12/23/2003 to 6/30/2006, US, UK and Japan are less 'endogenous' in the cointegrating system.

Table 4.10 Breitung (2002) Non-parametric Cointegration Test Results

Time Period	With Drift			Without Drift	
	$H_0: r=0$	$H_0: r=1$	$H_0: r=2$	$H_0: r=0$	$H_0: r=1$
1/1/1990 to 6/30/2006	2158.45**	748.00	—	2560.66	—
1/1/1990 to 9/2/1996	2006.47	—	—	2353.75	—
11/7/1997 to 12/22/2003	3217.20**	1521.24**	326.35	3636.62**	1892.37
12/23/2003 to 6/30/2006	2425.77**	629.36	—	3742.59**	1235.25

Note:

** Significant at 5% level;

Table 4.10 presents the results for Breitung's (2002) non-parametric cointegration test. For the full sample period, the test statistics yield mixed results, depending on whether a drift term is incorporated. However, the test suggests strong evidence of no non-parametric cointegration in the first sample period and at most two cointegration relationships in the second sub period. After 2003, one cointegration relationship is significant.

4.4.4 Summary of Cointegration Test Results

Table 4.11 Summary of the Cointegration Test Results

Test	Time Period			
	1/1/1990 to 6/30/2006	**1/1/1990 to 9/2/1996**	**11/7/1997 to 12/22/2003**	**12/23/2003 to 6/30/2006**
Johansen Test	No Cointegration	No Cointegration	1 CE	1 CE
Bieren Test	1 CE	No Cointegration	2 CE	1 CE
Breitung Test	Mixed	No Cointegration	2 CE	1 CE

Note:

CE refers to Cointegration Equation;

The Breitung Test for the full sample period is mixed, depending on whether a drift term is considered.

As has been pointed out by Bierens (1997), according to Monte Carlo simulation, non-parametric cointegration approach cannot completely replace traditional Johansen's approach, because the latter provides additional information, in particular regarding possible cointegration restrictions on the drift parameters, and the presence of linear trends in the cointegration relations. Therefore, it is suggested that parametric and non-parametric cointegration approaches work as complements to obtain a more accurate understanding of long-run equilibriums in nonstationray series. Table 4.11 summarizes the cointegration test results in this chapter.

From Table 4.11, it is observed that all cointegration tests provide clear evidence when structural breaks are taken into consideration. For the first sub period of 1/1/1990 to 9/2/1996, no cointegration relationship is found in the five securitized real estate markets. After 1997, there is strong evidence suggesting at least one cointegration relationship between these markets. However, for the full sample period without consideration of possible structural breaks, cointegration tests show mixed evidence. Therefore, structural break plays an important role in determining correct long-run equilibrium relationship. Failure to incorporate possible breaks will lead to erroneous and confusing results.

The evidence of cointegration in international securitized real estate markets after 1997 indicates that there is a long-run relationship between these markets. As a result, investors should be aware of the comovements in these markets as it may negatively affect the long-run international diversification benefits.

4.5 Summary

This chapter is the first empirical part of this study that investigates the structural breaks and long-run relationship in international securitized real estate markets. The main findings can be summarized as follows:

(a) Significant structural breaks are detected in both price and volatility indices in each securitized real estate market. Except for UK, the significant break points in prices occurred around year 1996 and 1997, which is consistent with the outburst of Asian financial crisis and the internet and high-tech bubble;

(b) All price series in these securitized real estate markets are nonstationray. Both Johansen and non-parametric cointegration tests show that there is a long-run stable relationship among these markets after 1997; whereas in the first sub period, no cointegration relationship is identified;

(c) The results indicate that the benefits of the long-run diversification in sample securitized real estate markets have been reduced after 1997, especially in Asian countries according to the restricted cointegration test results.

Chapter 5
Volatility Regimes and Short-term Linkages

5.1 Introduction

This chapter continues with second part of empirical investigation. The main objective is to model the short-term lead/lag interactions and comovements (return and volatility spillovers) in international securitized real estate markets with the consideration of multiple structural breaks in volatilities. Section 5.2 identifies the volatility regimes in each market. Section 5.3 introduces the Regime-dependent Asymmetric Dynamic Covariance Model, and Section 5.4 reports the estimation results for the model. The application is discussed in Section 5.5. The final section summarizes this chapter.

5.2 Identify Volatility Regimes

5.2.1 Structural Breaks in Volatilities

Based on the break dates detected in international securitized real estate markets (as reported in Table 4.2, Chapter 4), each market can be divided into different volatility regimes. Table 5.1 reports the average returns and volatilities for different regimes in each market.

Table 5.1 Return and Volatility Characteristics in Different Volatility Regimes

	Regime 1	Regime 2	Regime 3	Regime 4	Regime 5	Average	Median
US	1/1/90-	4/16/94-	6/6/98-	1/10/04-	—	—	—
	4/15/94	6/5/98	1/9/04	6/30/06			
Return	0.0388	0.0413	0.0095	0.0649	—	0.0334	0.0153
Vol[1]	0.6363	0.4432	0.8249	1.0101	—	0.7336	—
Vol[2]	1.3846	0.9750	1.6982	2.2371	—	1.5159	1.2351
t-stat[3]	—	5.72***	8.93***	-4.73***	—	—	—
UK	1/1/90-	10/9/93-	3/8/03-	—	—	—	—
	10/8/93	3/7/03	6/30/06				
Return	-0.0261	-0.0029	0.1214	—	—	0.0168	0.0000
Vol[1]	1.2816	0.8442	1.0730	—	—	1.0078	—
Vol[2]	2.7784	1.8817	2.3583	—	—	2.1826	1.8375
t-stat[3]	—	6.95***	3.61***	—	—	—	—
JP	1/1/90-	9/12/92-	10/18/97-	4/22/00-	11/15/03-	—	—
	9/11/92	10/17/97	4/21/00	11/14/03	6/30/06		
Return	-0.1308	0.0301	-0.0529	-0.0018	0.1153	-0.0023	-0.0664
Vol[1]	2.2881	1.7473	3.1170	2.1810	1.7033	2.1669	—
Vol[2]	5.1318	3.5613	6.5139	4.6688	3.5882	4.5112	3.7168
t-stat[3]	—	4.62***	7.76***	4.61***	-4.23***	—	—
HK	1/1/90-	6/7/97-	1/8/00-	11/29/03-	—`	—	—
	6/6/97	1/7/00	11/28/03	6/30/06			
Return	0.0679	-0.0479	-0.0158	0.0769	—	0.0314	0.0072
Vol[1]	1.5409	2.8818	1.8036	1.2963	—	1.8445	—
Vol[2]	3.1366	5.5792	3.5278	2.7173	—	3.6910	2.9076
t-stat[3]	—	-6.47***	-4.31***	5.47***	—	—	—
SG	1/1/90-	8/23/97-	2/12/00-	10/25/03-	—	—	—
	8/22/97	2/11/00	10/24/03	6/30/06			
Return	0.0279	-0.0968	-0.0343	0.1002	—	0.0070	-0.0112
Vol[1]	1.5093	3.6123	1.9637	1.1167	—	2.0416	—
Vol[2]	3.2349	7.4196	4.2700	2.2345	—	4.4312	3.0844
t-stat[3]	—	-8.06***	5.93***	-10.37***	—	—	—

Note:

All figures are in percentage;

Return is the mean of daily returns in each regime;

Vol[1] is the standard deviation of daily returns in each regime;

Vol[2] is the mean of constructed weekly volatility series in each regime;

t-stat[3] is the t test statistics of the null hypothesis that volatilities of every two contiguous regimes are equal;

*** Significant at 1% level.

A t-test is also carried out to verify the volatility difference between every two contiguous regimes. All the t-statistic are highly significant at 1% level, rejecting the null hypothesis that volatilities of every two contiguous regimes are equal, which suggests that the break points identified are robust.

The results of volatility breaks and the corresponding return and volatility characteristics in each regime can be summarized as follows.

(a) United States

For US, regime 1 and regime 2 have close average returns, 0.0388 and 0.0413 (daily in percentage) respectively; but the volatility of regime 1 is considerably larger than regime 2. This can be partially explained by the recovery process of the whole economy after the great market crash in 1987[1]. Switching from regime 1 to regime 2, the performance of the REIT sector has improved as the volatility lowered down and the average returns maintained at the same level. At the end of regime 2, huge capital began to rush into those high-tech stocks due to the technology and internet bubbles at that time, which caused the value of REIT share prices to fall by 20 percent in the first quarter of 1998. At the same time, the Asian crisis may have potential negative impact on international investor’s confidence and thus caused a drop of general market in US. As a result, the second break point is detected in this year, when the whole market switched to the third regime.

[1] On October 19, 1987, a date that subsequently became known as "Black Monday," the Dow Jones Industrial Average plummeted 508 points, losing 22.6% of its total value. The S&P 500 dropped 20.4%, falling from 282.7 to 225.06. This was the greatest loss Wall Street had ever suffered on a single day.

Regime 3 has the lowest average daily return of 0.0095%. Meanwhile the volatility is comparably high in this regime, which indicates that regime 3 is a tough time for REITs market in the US. During this period of time, US went through the burst of high-tech and internet bubble and the 9.11 terrorism attack, which seem to have significant negative impact on the REIT market. However, the REIT Modernization Act (RMA) was introduced in 1999, which is regarded as a major impetus for the popularity of REITs. After a few years, the market went up and switched into another regime. Regime 4 exhibits much higher return than regime 3, while the volatility maintains at a high level compared to the average level of the last decade. The high return associated with high volatility suggests that the REIT market in regime 4 is gradually recovering from the previous bad period, but yet to achieve a stable stage that is usually represented by high return with low volatility.

(b) United Kingdom

For the UK, only two structural breaks are detected so that three regimes are specified. Regime 1 corresponds to Jan 05, 1990, to Oct 08, 1993; regime 2 corresponds to Oct 09, 1993, to Mar 7, 2003; and regime 3 corresponds to Mar 8, 2003, to Jun 30, 2006.

Following the crash in 1987[2], regime 1 has a low return of -0.0261 and a high volatility of 1.2816. Another reason may be the rise of the interest rate at the late 1980s. In October 1989,

[2] By the end of October 1987, the stock market in UK has fallen 26.4%, taking several years to recover.

Nigel Lawson, who was the Chancellor of the Exchequer, raised bank base rates to 15%. With the bank base rates raised, the whole market recession followed at the end of 1989. Consequently, the property prices dropped severely due to the heavy debt incurred by the property companies. The interest rate hike, which was used to reduce the inflation, adversely affects the property market. From January 1990 to January 1993, the UK securitized property index dropped from 821.94 to 489.08 (FTSE Real Estate Index), decreasing nearly 25% per year. Starting from 1992, the interest rate fell in order to stimulate investment activity, and hence benefited the property market. Property companies took advantage of the booming stock market to repair their balance sheets. In 1993, the securitized real estate market in UK switched into regime 2, the recovering regime.

It seems that the securitized real estate market in UK was not affected by the Asian crisis as no structural break is detected around 1997. In March 2003, the market entered regime 3, which has a very high average return of 0.1214 and a fairly high volatility of 1.0730. This could be attributed to the good performance of the world economy after 2003, as many other countries also saw a boost in their markets during this period. However, the relatively high volatility signals caution for investors.

(c) Japan

For Japan, four break points are detected, suggesting 5 regimes in the securitized real estate market. Regime 1 has a very low return of -0.1308 associated with a high volatility of

2.2881. The Japanese economy hit a peak in late 1980s and the recession occurred afterwards. The real estate index value reached a peak at 2429.43 (TOPIX Real Estate Index) on Dec 15, 1989. At the beginning of 1990, the bubble collapsed and the market was immersed in recession. According to Ministry of Construction, in November 1991 houses and apartments in metropolitan Tokyo had lost 37% of their value and plots of land in the suburb of Saitama had lost 41%, comparing to the preceding year. On the other hand, the existing stock of office space in the Great Tokyo (includes city of Tokyo, Kanagawa, Chiba, and Saitama Prefectures) continued to climb up until 1997, according to research by the Japan Ministry of Home Affairs. In 1997, the total office stock approached a peak of 20,000 hectares in this area. At the same time, the nominal gross residential investment reached a peak of 30 trillion yen in 1996. The growing investment in office and residential space explains the slight improvement of the market performance in regime 2. Unfortunately, this trend did not last long. In 1997 the market dropped again and the situation did not become better until 2003.

In regime 3, the daily average return of Japanese securitized real estate market is -0.0529, and the volatility is the highest among all regimes. It seems that the Asian crisis in 1997 did have negative impact on Japanese market. In April 2000, the market turned a little better and entered regime 4, in which the return is close to zero. After 2003, the Japanese securitized real estate market seemed to recover from previous hard time. In regime 5, the average return rises to 0.1153, while the volatility drops to 1.7033.

(d) Hong Kong

For Hong Kong, the first significant break point also occurs at 1997, which indicates that Hong Kong has not been immune from Asian crisis. This is consistent with the study carried out by Wilson and Zurbruegg (2004), who found significant contagion effect in Asian-Pacific securitized real estate markets during the 1997 crisis. From October 1997 to July 1998, the real estate market in Hong Kong declined by nearly 30%. The average daily return dropped from 0.0679 of regime 1 to -0.0479 of regime 3, whereas the volatility almost doubled from 1.5409 to 2.8818. In the recession period of 1997 to 1999, the index value shrank more than 50 percent. After 2000, the situation became a little better. With China's entrance into WTO and the CEPA (Closer Economic Partnership Agreement), Hong Kong's economy became more integrated with China Mainland. The recovery of domestic consumption and influx of Mainland tourists have driven up the whole economy and the retail property market. Regime 3 can be regarded as a post-crisis period when the return increases and the volatility drops. The market turned much better at the end of 2003. In 2004, the price of mass residential properties increased by 35.3%. In regime 4, the average return reaches the highest of 0.0769, whereas the volatility drops to 1.2963, indicating a favorable real estate market environment in Hong Kong.

(e) Singapore

For Singapore, four volatility regimes are specified. Since the 1980s, Singapore experienced tremendous growth in the economy, to which commercial and industrial property developments contributed substantially. From 1986 to 1993, private residential prices rose by 156%. Driven by a combined influence of high prospective capital gains and low interest rates, private property prices in Singapore followed an almost uninterrupted uptrend since 1986. In regime 1, the average return is fairly high at 0.0279, and the volatility is at a low level of 1.5093.

However, as the property prices reached its highest point, investment purchase increasingly turned speculative, with investors selling their options on new property developments for handsome profits. Therefore the government introduced anti-speculation measures in the residential market in May 1996, which, along with the subsequent Asian financial crisis in 1997, caused prices of the Singapore real estate market to decline dramatically in later years. With the market switched from regime 1 to regime 2 in August 1997, the average return fell from 0.0279 to -0.0968; whereas the volatility increased from 1.5093 to 3.6123. In 2000 the market experienced a recovery from the crisis, but the average return remained negative. After 2003, with the boost of the economy and the improving world investment environment, the market switched into regime 4 which has a very high average return of 0.1002 associated with a quite low volatility of 1.1167.

To sum up, for Asian markets, namely Japan, Hong Kong, and Singapore, significant volatility break dates are detected within the time period of June 6, 1997, to Oct 17, 1997, which are consistent with the existing studies addressing the issue of Asian financial crisis in such period. The Asian crisis seems to have no impact on UK real estate market. Although a break was detected in 1998 in US, there is no convincing evidence that links such break to Asian crisis happened one year before. It is more reasonable to attribute such break to the turnover of the market that was caused by the irrational bubble in IT industry. All the five markets have a significant break point around 2003 to 2004, and after that the markets exhibit high return and low volatility, which indicates a favorable time for real estate investment.

5.2.2 Volatility Regime Types

In terms of return and volatility characteristics in each regime, four regime types are defined (Table 5.2). Regime I corresponds to the time period associated with low return and high volatility, i.e. the most stressed period. Regime IV corresponds to the period that has high return and low volatility, when the market has the best performance. Regime II and regime III are the periods that have low return and low volatility, and high return and high volatility, respectively. Practically, regime I is the crisis period and regime IV is the bull market period; whereas regime II and regime III are the transitional periods. It is also expected that the market will follow a cycle from regime I to regime IV.

Table 5.2 Volatility Regime Definition

		Return	
		Low	High
Volatility	High	Regime I	Regime III
	Low	Regime II	Regime IV

The empirical evidence of the regime cycles in international securitized real estate markets is presented in Figure 5.1[3]. The securitized real estate market in the United States exhibits the characteristics of regime I, III, and IV in the full sample period. However, the period with low return and low volatility, namely regime II, was not found. For UK, the market exhibits the characteristics of regime I at the beginning of 1990s. After the break point on 1993, it enters regime II, which lasts for almost 10 years. The relatively low return and low volatility suggests, to some extent, the lack of investor's confidence in the securitized real estate market in UK during this period. In 2003, the market switches to regime III, with the return increases enormously and the volatility goes up as well. Regime IV, a period that indicates a real bull market condition, was not found in UK.

The Japanese market is the most complex one. The crisis period (Regime I) was identified in two regimes, regime 1 of 1990 to 1992 and regime 3 of 1997 to 2000. After crisis periods, the market recovered with a conspicuous increase in returns and a significant decline in volatilities. The situations in the securitized real estate markets of Hong Kong and Singapore are quite similar. Starting from 1990, both Hong Kong and Singapore enjoyed a bull market period until 1997, the year of the Asian financial crisis. As in the chart, the returns drop dramatically with the volatility almost doubled. After that the markets gradually recovered, and finally reach another bull period after 2003.

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[3] In order to be compared to the weekly volatility series, weekly returns are used for illustration in Figure 5.1.

Figure 5.1 Regime Breaks in Securitized Real Estate Markets

Panel A. United States | **Panel B. United Kingdom**

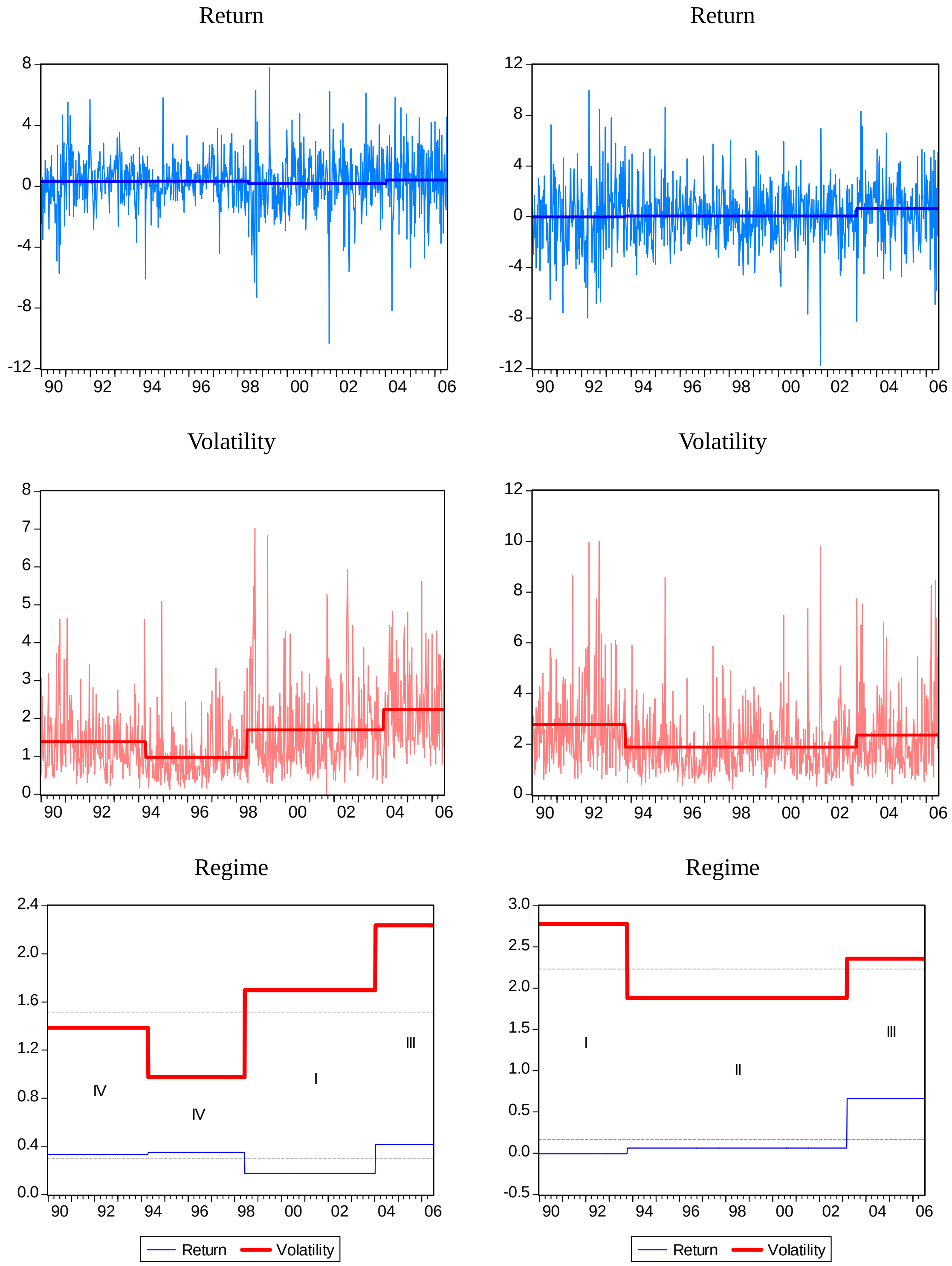
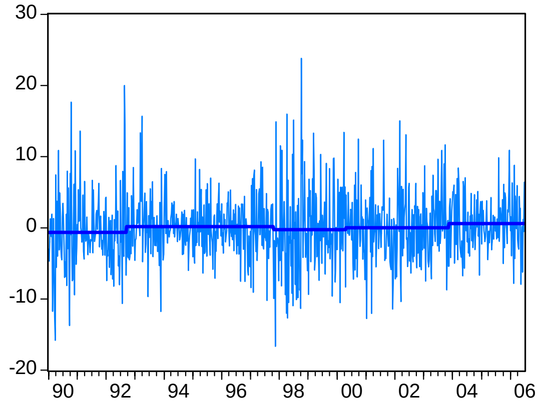


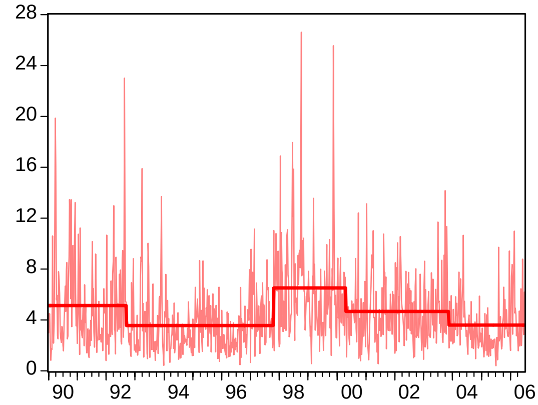
Figure 5.1 Regime Breaks in Securitized Real Estate Markets (Continued)

Panel C. Japan

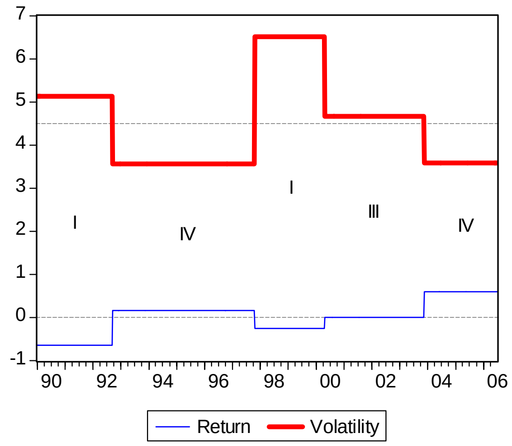
Return



Volatility

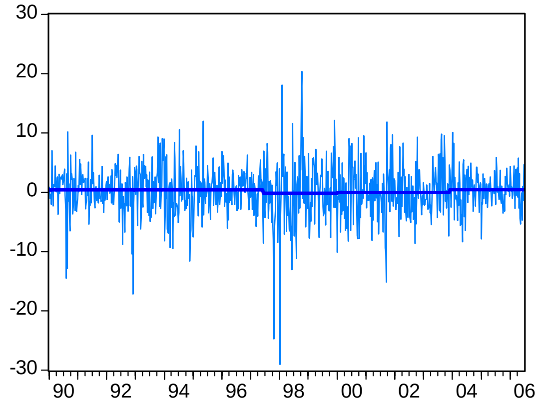


Regime

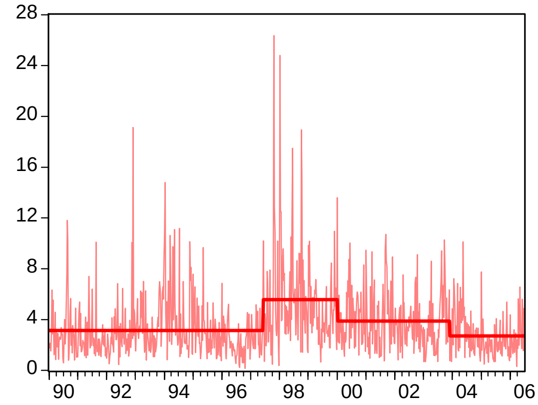


Panel D. Hong Kong

Return



Volatility



Regime

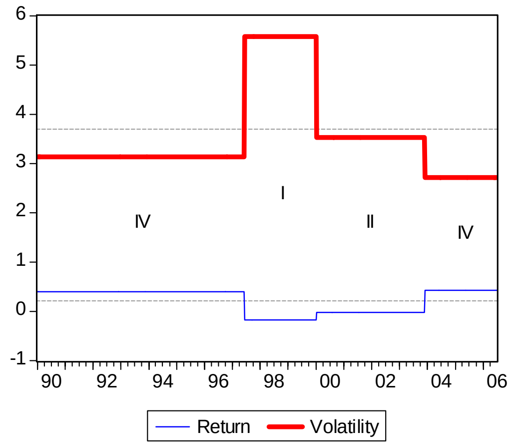
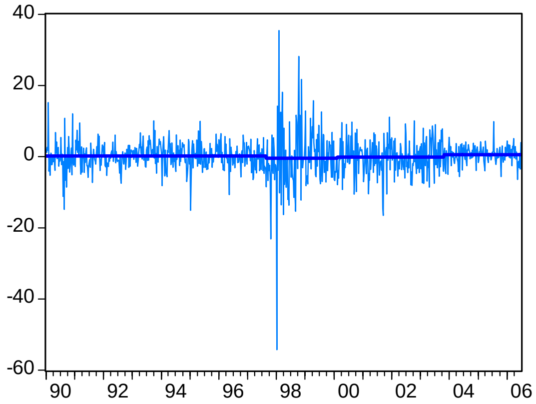


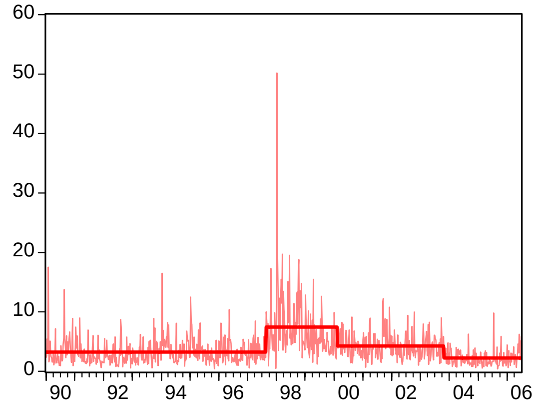
Figure 5.1 Regime Breaks in Securitized Real Estate Markets (Continued)

Panel E. Singapore

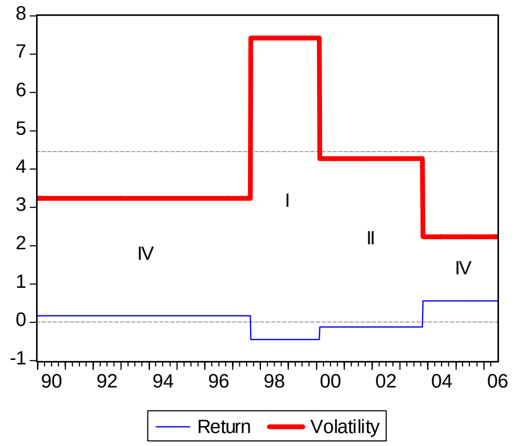
Return



Volatility



Regime



In general, Asian securitized real estate markets are now in a golden period enjoying high returns and low volatilities. For the US and the UK, they are also in the regimes of high return, but the volatility remains high as well. Another interesting phenomenon is that the regime types occur in sequence to form a market cycle in all securitized real estate markets. For example, regime III is not following a regime IV, but rather occurring after a regime II. This indicates that the breakdown of a market is usually not predicted, whereas a recovery process of a market from crisis would probably take a very long time step by step.

5.3 Volatility Model Specification

As mentioned in Section 2.4.2, ARCH models have been successfully applied to financial time series to model heteroskedasticity since Engle's seminal paper on 1982. The ARCH model was extended to generalized ARCH (GARCH) model by Bollerslev in 1986. Bollerslev et al. (1992) have cited over 200 applications to financial data. In addition, the development of multivariate GARCH (MGARCH) models from the original univariate specifications represents a major step forward in the modeling of time series. Modeling the returns simultaneously has several advantages over the univariate approach that has been used so far. First, it eliminates the two-step procedure, thereby avoiding problems associated with the estimated regressors. Second, it improves the efficiency and the power of the tests for cross market spillovers. Third, it is methodologically consistent with the notion that spillovers are essentially manifestations of the impact of global news on any given market.

The multivariate GARCH models have been among the most widely used time-varying covariance models. These models include the VECH model of Bollerslev, Engle, and Wooldridge (1988), the constant correlation (CC) model of Bollerslev (1990), the factor ARCH (FARCH) model of Engle, Ng, and Rothschild (1990), the BEKK model of Engle and Kroner (1995), the Asymetric Dynamic Covariance model (ADC) of Kroner and Ng (1998), and the Dynamic Conditional Correlation (DCC) model of Engle (2002) and Tse and Tsui (2002). These models have been applied to many markets and many asset pricing and investment problems. The Asymmetric Dynamic Covariance (ADC) Matrix Model proposed by Kroner and Ng (1998) is a generalization of various multivariate GARCH models. It will reduce to different type of multivariate GARCH models in different conditions. Modeling the conditional variance and covariance by ADC will allow for asymmetric volatility spillover effects to be observed, along with accounting for an asymmetry in the correlation dynamics from negative and positive news shocks entering both the markets. This is of invaluable importance given it has been shown that, for more common equity indices, asymmetric effects can be quite large and can have an impact on the benefits to diversification (see Martens and Poon, 2001).

However, a common problem associated with all ARCH type models, as argued by Lamoreux and Lastrapes (1990), is that the ARCH estimates are seriously affected by structural changes. This might explain why ARCH models show an extremely high degree of persistence, weak forecasting, and a poor statistical description of outliers. As stated in the previous section, the international securitized real estate markets show clear evidence of changes of regime in volatilities. In order to address this issue, based on Kroner and Ng (1998), the Regime-dependent Asymmetric Dynamic Covariance VAR model (RDADC) is proposed as follows.

Let $R_{i,t}$ be the percentage return at time t for market i where, i = 1,2,…5, (1 = United States (US), 2 = United Kingdom (UK), 3 = Japan (JP), 4 = Hong Kong (HK), 5 = Singapore (SG)), Ω_{t-1} the all information available at time $t-1$, $\mu_{i,t}$ and $\sigma_{i,t}^2$ the conditional mean and the conditional variance respectively, $\sigma_{ij,t}$ the conditional covariance between the market i and market j, $\varepsilon_{i,t}$ the innovation at time t (i.e., $\varepsilon_{i,t} = R_{i,t} - \mu_{i,t}$), and $z_{i,t}$ the standardized innovation (i.e., $z_{i,t} = \varepsilon_{i,t} / \sigma_{i,t}$). The regime-dependent ADC model is defined as:

$$R_{i,t} = \beta_{i,0} + \sum_{j=1}^{5} \beta_{ij} R_{j,t-1} + \varepsilon_{i,t}$$

$$H_t = D_t R D_t + \Phi \circ \Theta_t \,,$$

where

H_t is the conditional variance/covariance matrix, i.e. $H_t = \begin{bmatrix} \sigma_{11,t} & \cdots & \sigma_{1n,t} \\ \vdots & \ddots & \vdots \\ \sigma_{1n,t} & \cdots & \sigma_{nn,t} \end{bmatrix}$;

$D_t = [d_{ij,t}]$, $d_{ii,t} = \sqrt{\theta_{ii,t}}$ for all i, $d_{ij,t} = 0$ for all $i \neq j$;

$\Theta_t = [\theta_{ij,t}]$;

$R = [r_{ij}]$, $r_{ii} = 1$ for all i, $r_{ij} = \rho_{ij}$ for all $i \neq j$;

$\Phi = [\phi_{ij}]$, $\phi_{ii} = 0$ for all i;

$$\frac{\theta_{ij,t}}{\sqrt{\gamma_{i,R}\gamma_{j,R}}} = \omega_{ij} + B \circ H_{t-1} + \alpha_i' \begin{bmatrix} \frac{\varepsilon_{11,t}}{\gamma_{1,R}} & \cdots & \frac{\varepsilon_{1n,t}}{\sqrt{\gamma_{1,R}\gamma_{n,R}}} \\ \vdots & \ddots & \vdots \\ \frac{\varepsilon_{n1,t}}{\sqrt{\gamma_{n,R}\gamma_{1,R}}} & \cdots & \frac{\varepsilon_{nn,t}}{\gamma_{n,R}} \end{bmatrix} \alpha_j + g_i' \begin{bmatrix} \frac{\eta_{11,t}}{\gamma_{1,R}} & \cdots & \frac{\eta_{1n,t}}{\sqrt{\gamma_{1,R}\gamma_{n,R}}} \\ \vdots & \ddots & \vdots \\ \frac{\eta_{n1,t}}{\sqrt{\gamma_{n,R}\gamma_{1,R}}} & \cdots & \frac{\eta_{nn,t}}{\gamma_{n,R}} \end{bmatrix} g_j$$

for all i, j; (5.1)

B is an asymmetric $n \times n$ matrix;

a_i and g_i, $i = 1,...,n$ are $n \times 1$ vectors of parameters;

ω_{ij}, ρ_{ij}, ϕ_{ij}, $\gamma_{i,R}$ and $\gamma_{j,R}$, $i, j = 1,...,n$, $R \in [I, II, III, IV]$, are scalars;

$\eta_{i,t} = \max[0, -\varepsilon_{i,t}]$ and $\eta_t = [\eta_{1,t},...,\eta_{n,t}]'$.

The ADC model is employed because of two of its appealing features. First, it permits asymmetry in both the conditional variance and the conditional covariance. The asymmetry is captured by the term $g_i' \eta_{t-1} \eta_{t-1}' g_j$. Second, and as noted at the beginning of this section, it nests several well-known time varying multivariate GARCH variance and covariance models.

For the Regime-dependent ADC model used here, consider the following set of conditions:

(i) $\rho_{ij} = 0$ for all $i \neq j$;

(ii) $a_i = \alpha_i \iota_i$, $b_i = \beta_i \iota_i$, and $g_i = \varphi_i \iota_i$ for all i, where ι_i is the ith column of an $n \times n$ identity matrix, and α_i, β_i, and φ_i, $i = 1,...,n$ are scalars;

(iii) $\phi_{ij} = 0$ for $i \neq j$;

(iv) $\phi_{ij} = 1$ for all $i \neq j$;

(v) $A = \alpha(\omega\lambda')$, $B = \beta(\omega\lambda')$, and $G = \varphi(\omega\lambda')$ where $A = [a_1,...,a_n]$, $B = [b_1,...,b_n]$, and $G = [g_1,...,g_n]$, ω and λ are $n \times 1$ vectors, and α, β, and φ are scalars;

(vi) $\gamma_{i,R} = \gamma_{j,R} = 1$.

The Regime-dependent ADC model will reduce to the different asymmetric multivariate GARCH models under different combinations of these conditions. Specifically, the RADCEC model will become an normal ADC model under condition (vi), an asymmetric VECH model under conditions (i), (ii), and (vi), an asymmetric Constant Correlation model under conditions (ii), (iii), and (vi), an asymmetric BEKK model under conditions (i), (iv) and (vi), and an asymmetric FARCH model under conditions (i), (iv), (v) and (vi).

5.4 Empirical Results

Before estimating the RDADC model, a restricted model called Generalized Dynamic Covariance (GDC) model is estimated as a benchmark. The different between the GDC model and the RDADC model is that GDC model does not include the asymmetric effects and the volatility regime effects. That is, in Equation (5.1), $\gamma_{i,R} = \gamma_{j,R} = 1$ and $\eta_{i,t} = 0$. The estimation results for the benchmark GDC model is presented in Table 5.3.

Table 5.3 Results from Generalized Dynamic Covariance (GDC) Model

GDC Model Specification:

$$R_{i,t} = \beta_{i,0} + \sum_{j=1}^{5} \beta_{ij} R_{j,t-1} + \varepsilon_{i,t}\,; \qquad H_t = D_t R D_t + \Phi \circ \Theta_t\,; \qquad \theta_{ij,t} = \omega_{ij} + B \circ H_{t-1} + \alpha_i' \begin{bmatrix} \varepsilon_{11,t} & \cdots & \varepsilon_{1n,t} \\ \vdots & \ddots & \vdots \\ \varepsilon_{n1,t} & \cdots & \varepsilon_{nn,t} \end{bmatrix} \alpha_j\,;$$

$$D_t = [d_{ij,t}];\; d_{ii,t} = \sqrt{\theta_{ii,t}}\,;\; d_{ij,t} = 0\,; \qquad \Theta_t = [\theta_{ij,t}]\,; \qquad R = [r_{ij}]\,; r_{ii} = 1; r_{ij} = \rho_{ij}\,; \qquad \Phi = [\phi_{ij}]\,, \phi_{ii} = 0$$

To	From									
	US		UK		JP		HK		SG	
Panel A: Return Transmission										
US	0.1812***	(0.0186)	0.0093	(0.0098)	-0.0093**	(0.0046)	-0.0055	(0.0060)	0.0072	(0.0054)
UK	0.1491***	(0.0202)	0.0831***	(0.0176)	0.0023	(0.0070)	0.0026	(0.0089)	-0.0167**	(0.0078)
JP	0.2552***	(0.0412)	0.0691**	(0.0309)	0.0853***	(0.0171)	0.0242	(0.0182)	0.0123	(0.0173)
HK	0.3469***	(0.0321)	0.0800***	(0.0224)	-0.0247**	(0.0115)	0.0945***	(0.0172)	-0.0001	(0.0144)
SG	0.2690***	(0.0327)	0.0617***	(0.0228)	-0.0139	(0.0117)	0.0574***	(0.0152)	0.0520***	(0.0158)
$\beta_{i,0}$	0.0409***	(0.0092)	0.0294**	(0.0147)	0.0070	(0.0287)	0.0460**	(0.0225)	0.0339	(0.0236)
Panel B: Volatility Transmission										
US	0.3222***	(0.0158)	0.0017	-0.0299	-0.0067	(0.0058)	0.0177	(0.0154)	-0.0080	(0.0055)
UK	0.0480***	(0.0089)	0.2313***	(0.0160)	0.0071	(0.0074)	-0.0121	(0.0092)	-0.0019	(0.0076)
JP	0.0412	(0.0510)	-0.0260	(0.0319)	0.2752***	(0.0177)	-0.1108***	(0.0265)	0.0986***	(0.0190)
HK	-0.0407	(0.0305)	0.0115	(0.0279)	-0.0701***	(0.0123)	0.2886***	(0.0162)	0.0342*	(0.0192)
SG	0.0622***	-0.0241	-0.0616***	(0.0202)	-0.0035	(0.0143)	0.0733***	(0.0161)	0.2569***	(0.0173)
B_{ii}	0.8708***	(0.0110)	0.9335***	(0.0088)	0.9033***	(0.0122)	0.8893***	(0.0103)	0.9049***	(0.0099)

Table 5.3 Results from Generalized Dynamic Covariance (GDC) Model (Continued)

Panel C: Other Coefficients

ω_{US}	-0.0259	(0.0749)	ω_{JPSG}	0.0741	(0.1336)	ρ_{HKSG}	0.0361 *	(0.0201)
ω_{USUK}	0.0284	(0.0773)	ω_{HKSG}	0.1291	(0.2746)	ϕ_{USUK}	0.2865 **	(0.1114)
ω_{UK}	-0.0338	(0.1331)	ω_{SG}	-0.1534	(0.2572)	ϕ_{USJP}	0.0258	(0.0322)
ω_{USJP}	0.0450	(0.0822)	ρ_{USUK}	0.0254 *	(0.0131)	ϕ_{USHK}	0.3530 ***	(0.1231)
ω_{UKJP}	-0.0668	(0.1002)	ρ_{USJP}	0.0722 **	(0.0300)	ϕ_{USSG}	0.1771	(0.1278)
ω_{JP}	-0.1761	(0.1492)	ρ_{USHK}	0.0372	(0.0229)	ϕ_{UKJP}	0.2881 ***	(0.1106)
ω_{USHK}	-0.0658	(0.0656)	ρ_{USSG}	0.0561 *	(0.0307)	ϕ_{UKHK}	0.2891	(0.2211)
ω_{UKHK}	0.0861	(0.0867)	ρ_{UKJP}	0.0090	(0.0106)	ϕ_{UKSG}	0.7103 ***	(0.1695)
ω_{JPHK}	0.1546	(0.1735)	ρ_{UKHK}	0.1228 *	(0.0720)	ϕ_{JPHK}	0.4017 ***	(0.1494)
ω_{HK}	-0.0817	(0.1496)	ρ_{UKSG}	0.2068 ***	(0.0400)	ϕ_{JPSG}	0.3967 ***	(0.1341)
ω_{USSG}	0.0361	(0.0748)	ρ_{JPHK}	0.2733 ***	(0.0835)	ϕ_{HKSG}	0.5438 ***	(0.0531)
ω_{UKSG}	-0.0100	(0.1245)	ρ_{JPSG}	0.0641	(0.0396)			

Note:

*** Significant at 1% level; ** Significant at 5% level;* Significant at 10% level;

Figures in brackets are standard errors.

The results consist of three major parts: the return transmission coefficients, the volatility transmission coefficients, and other coefficients such as the ρ_{ij} and ϕ_{ij}. Significant multidirectional transmissions are found in both returns and volatilities in these securitized real estate markets. The US market is the most influential one in terms of the return spillovers, because all other four markets are significantly impacted by the lagged return in the US market. For the volatility spillovers, it is observed that all Asian markets do not have influence upon US or UK markets. Furthermore, the conditional volatility in UK is affected by the past innovation in the US market, but not vice versa. Most of the estimates of ρ_{ij} and ϕ_{ij} are significant, indicating that the GDC/ADC model provides additional information that any other specialized models fail to capture. The diagnostic statistics for the GDC model is presented in Table 5.4. Compared to Table 3.2 in Chapter 3, the Ljung-Box statistics for squared standardized residuals and the ARCH LM test results in Table 5.4 suggests that the ARCH effects have been well captured in the GDC model.

Table 5.4 Diagnostic Statistics of the GDC Model

	US	UK	JP	HK	SG
Ljung-Box statistic for up to 6 and 12 lags					
Q(6) for z_i	46.64**	27.56**	9.25	20.20**	9.52
Q(12) for z_i	64.57**	30.63**	13.36	24.16**	28.36**
Q(6) for z_i^2	8.93	7.49	12.56	1.72	13.8**
Q(12) for z_i^2	19.86*	16.05	20.23	3.01	15.75
ARCH LM test					
4 lags	2.83	3.07	3.05	0.47	8.64*
8 lags	8.36	4.75	8.71	1.18	12.84
12 lags	20.21*	13.60	14.32	1.97	13.95

Note:

Data in percentage.

** Significant at 5% level; * Significant at 10% level;

[a] Kolmogorov-Smirnov test for normality.

Next the full Regime-dependent Asymmetric Dynamic Covariance (RDADC) model is estimated and the results are presented in Table 5.5.

Panel A is the estimation results of the conditional mean equation, i.e. the transmission of returns. The VAR lag is determined by both AIC and SC, both suggesting an optimum lag of order 1. From Table 5.5, it can be seen that there are several significant multidirectional lead/lag relationships in the markets. First, all the securitized real estate markets are highly affected by their own returns in the last period, indicating a large extent of persistence in returns. For the return transmission across borders, the evidence is more complex. In consistency with the GDC results, the past return in the US securitized real estate markets has substantial impact on the current returns in other markets. The highly significant coefficients suggest that the US market is the most powerful one in terms of return spillovers.

At the same time, no market is found to have significant impact on the returns in the US market. For the UK, the past return in UK has significant influence on Asian markets, including Japan, Hong Kong and Singapore, and only Singapore has a return feedback for UK market. The Japanese market is affected by the US and the UK. For Hong Kong, it is affected by the US, the UK, and Japan, whereas Hong Kong does not have the influence on these three developed economies. The securitized real estate markets in Hong Kong and Singapore are highly correlated as expected, but it seems Hong Kong is more influential than Singapore as the return transmission is unidirectional from Hong Kong to Singapore. Concerning the sign of the return transmission, most of them are positive, including all the coefficients indicating persistence in each market, i.e. the β_{ii}. Only Japan and Singapore have two significant negative coefficients, suggesting that there is some degree of short-term diversification benefits in these countries. This can also be verified by the relatively small correlation coefficients in Table 3.3 in Chapter 3.

Panel B presents the estimation results for the volatility interdependencies among these securitized real estate markets. The persistent parameters (B_{ii}) of the conditional variance are highly significant and close to 1, as commonly expected and is consistent with previous studies. In addition, all the parameters that capture the impact of the own innovation in the last period in each market are highly significant.

The current conditional volatility in the securitized real estate market in US is only affected by its own past innovation, which is consistent with the result in return transmission. As a result, the US REIT market seems to be isolated from shocks from other securitized real estate markets in terms of both return and volatility. However, other markets do receive significant impact originated from the US REIT market. For example, the past innovation in US has a significant influence on the current conditional volatility of the UK and Singapore. For Japan, there is no statistical significance attributed to a shock arriving from Japan affecting the conditional variance in the US and the UK, and vice versa. This reconfirms that Japan is more related to the Asian markets, as we predicted from the correlation coefficients stated in Table 3.3 in Chapter 3. As city-based economies and global financial centers, Hong Kong and Singapore are highly correlated, with volatility spillover from both directions.

Table 5.5 Results from the Regime-dependent Asymmetric Dynamic Covariance (RDADC) Model

RDADC Model Specification:

$$R_{i,t} = \beta_{i,0} + \sum_{j=1}^{5} \beta_{ij} R_{j,t-1} + \varepsilon_{i,t}\,; H_t = D_t R D_t + \Phi \circ \Theta_t\,;\ \frac{\theta_{ij,t}}{\sqrt{\gamma_{i,R}\gamma_{j,R}}} = \omega_{ij} + B \circ H_{t-1} + \alpha_i' \begin{bmatrix} \frac{\varepsilon_{11,t}}{\gamma_{1,R}} & \cdots & \frac{\varepsilon_{1n,t}}{\sqrt{\gamma_{1,R}\gamma_{n,R}}} \\ \vdots & \ddots & \vdots \\ \frac{\varepsilon_{n1,t}}{\sqrt{\gamma_{n,R}\gamma_{1,R}}} & \cdots & \frac{\varepsilon_{nn,t}}{\gamma_{n,R}} \end{bmatrix} \alpha_j + g_i' \begin{bmatrix} \frac{\eta_{11,t}}{\gamma_{1,R}} & \cdots & \frac{\eta_{1n,t}}{\sqrt{\gamma_{1,R}\gamma_{n,R}}} \\ \vdots & \ddots & \vdots \\ \frac{\eta_{n1,t}}{\sqrt{\gamma_{n,R}\gamma_{1,R}}} & \cdots & \frac{\eta_{nn,t}}{\gamma_{n,R}} \end{bmatrix} g_j\,;$$

$$D_t = [d_{ij,t}];\ d_{ii,t} = \sqrt{\theta_{ii,t}}\,;\ d_{ij,t} = 0\,;\qquad \Theta_t = [\theta_{ij,t}];\qquad R = [r_{ij}]\,; r_{ii} = 1; r_{ij} = \rho_{ij}\,;\qquad \Phi = [\phi_{ij}]\,, \phi_{ii} = 0$$

To	From									
	US		**UK**		**JP**		**HK**		**SG**	
Panel A: Return Transmission										
US	0.1912 ***	(0.0175)	0.0058	(0.0094)	-0.0076	(0.0042)	-0.0034	(0.0057)	0.0065	(0.0051)
UK	0.1540 ***	(0.0213)	0.0784 ***	(0.0165)	0.0028	(0.0066)	0.0067	(0.0087)	-0.0165 **	(0.0075)
JP	0.2497 ***	(0.0394)	0.0704 **	(0.0281)	0.0777 ***	(0.0153)	0.0276	(0.0168)	0.0093	(0.0176)
HK	0.3510 ***	(0.0298)	0.0786 ***	(0.0123)	-0.0280 ***	(0.0106)	0.1008 ***	(0.0155)	-0.0010	(0.0152)
SG	0.2800 ***	(0.0312)	0.0697 ***	(0.0211)	-0.0185	(0.0116)	0.0650 ***	(0.0170)	0.0581 ***	(0.0174)
$\beta_{i,0}$	0.0254 ***	(0.0084)	0.0124	(0.0133)	-0.0404	(0.0269)	0.0349 *	(0.0190)	0.0138	(0.0211)
Panel B: Volatility Transmission										
US	0.2888 ***	(0.0242)	0.0062	(0.0136)	-0.0014	(0.0064)	-0.0097	(0.0084)	0.0050	(0.0079)
UK	-0.0645 **	(0.0302)	0.2232 ***	(0.0219)	0.0180	(0.0107)	-0.0156	(0.0120)	-0.0103	(0.0117)
JP	0.0662	(0.0660)	-0.0339	(0.0456)	0.2262 ***	(0.0202)	0.0703 **	(0.0329)	-0.0730 ***	(0.0263)
HK	-0.0092	(0.0474)	0.0536	(0.0334)	-0.0445 ***	(0.0170)	0.2672 ***	(0.0194)	-0.1180 ***	(0.0178)
SG	0.0746 *	(0.0396)	-0.0700 **	(0.0293)	0.0193	(0.0154)	-0.0948 ***	(0.0251)	0.2456 ***	(0.0215)

Table 5.5 Results from the Regime-dependent Asymmetric Dynamic Covariance (RDADC) Model (Continued)

	From									
To	US		UK		JP		HK		SG	
Panel B: Volatility Transmission (Continued)										
B_{ii}	0.7330 ***	(0.0297)	0.8411 ***	(0.0265)	0.8685 ***	(0.0160)	0.8577 ***	(0.0145)	0.8439 ***	(0.0209)
Panel C: Asymmetric Volatility Transmission										
US	-0.2218 ***	(0.0367)	-0.0552 ***	(0.0182)	-0.0151	(0.0095)	-0.0574 ***	(0.0085)	0.0488 ***	(0.0112)
UK	-0.1446 ***	(0.0353)	-0.1530 ***	(0.0336)	0.0235	(0.0216)	-0.0492 ***	(0.0187)	0.0273	(0.0229)
JP	0.1728	(0.0893)	0.0091	(0.0596)	-0.2971 ***	(0.0338)	0.1719 ***	(0.0444)	-0.1450 ***	(0.0386)
HK	0.2204 ***	(0.0618)	-0.0879	(0.0567)	0.1226 ***	(0.0266)	-0.2006 ***	(0.0380)	-0.1533 ***	(0.0300)
SG	0.0770	(0.0632)	-0.1208 ***	(0.0439)	0.1186 ***	(0.0325)	-0.1167 ***	(0.0312)	-0.2020 ***	(0.0334)
Panel D: Regime Indicating Factors										
I	3.0088 ***	(0.1863)	2.4202 ***	(0.1241)	2.0734 ***	(0.1002)	3.1540 ***	(0.1840)	4.7870 ***	(0.2957)
II	—		—		—		1.6572 ***	(0.0845)	2.1047 ***	(0.1076)
III	3.2559 ***	(0.1913)	1.5758 ***	(0.0843)	1.6306 ***	(0.0868)	—		—	
Panel E: Other Coefficients										
ω_{US}	0.0502	(0.1140)		ω_{JPSG}	0.2198	(0.1767)		ρ_{HKSG}	0.1426 ***	(0.0213)
ω_{USUK}	-0.0842	(0.0671)		ω_{HKSG}	0.1262	(0.2250)		ϕ_{USUK}	0.1876 **	(0.0757)
ω_{UK}	0.1056	(0.2076)		ω_{SG}	-0.1787	(0.2685)		ϕ_{USJP}	0.2210	(0.1453)
ω_{USJP}	-0.0975	(0.1460)		ρ_{USUK}	0.0266 *	(0.0154)		ϕ_{USHK}	0.2138	(0.1365)
ω_{UKJP}	0.0880	(0.3326)		ρ_{USJP}	0.0304	(0.0291)		ϕ_{USSG}	0.0306	(0.0191)
ω_{JP}	0.0299	(0.4464)		ρ_{USHK}	0.0974	(0.0675)		ϕ_{UKJP}	0.2375 ***	(0.0850)
ω_{USHK}	0.0306	(0.1828)		ρ_{USSG}	0.0116 *	(0.0068)		ϕ_{UKHK}	-0.0129	(0.0870)
ω_{UKHK}	-0.1117	(0.1794)		ρ_{UKJP}	0.0050	(0.0076)		ϕ_{UKSG}	0.2441 **	(0.1060)
ω_{JPHK}	-0.1886 *	(0.1075)		ρ_{UKHK}	0.1374 **	(0.0633)		ϕ_{JPHK}	0.0914 **	(0.0378)

Table 5.5 Results from the Regime-dependent Asymmetric Dynamic Covariance (RDADC) Model (Continued)

Panel E: Other Coefficients (Continued)

ω_{HK}	-0.0855	(0.2061)		ρ_{UKSG}	0.2740 ***	(0.0290)		ϕ_{JPSG}	0.7209 ***	(0.1842)
ω_{USSG}	-0.0235	(0.2400)		ρ_{JPHK}	0.0555	(0.0486)		ϕ_{HKSG}	0.5421 ***	(0.0645)
ω_{UKSG}	0.1207	(0.2567)		ρ_{JPSG}	0.1077 **	(0.0447)				

Note:

*** Significant at 1% level; ** Significant at 5% level;* Significant at 10% level;

Figures in brackets are standard errors.

The estimates of asymmetric (sometimes called ‘leverage’) volatility transmission effects in these markets are presented in Panel C. As has been well documented by Black (1976) and Nelson (1991), among many others, a stock price decrease tends to increase subsequent volatility by more than would a stock price increase of the same magnitude. In Panel C of Table 5.5, all the diagonal coefficients are significant, indicating the existence of the asymmetric effect in the transmission of own past innovations in all securitized real estate markets.

The past negative innovation in the US securitized real estate market has significant impact over the markets in the US, the UK, and Hong Kong. It is also noteworthy that Asian countries are highly intercorrelated in volatility and are sensitive in response to the negative impact from other markets. Japan, in consistency with the previous general volatility spillover, does not have any significant asymmetric connections with the US and the UK.

Panel D of Table 5.5 is the results of the regime effects, i.e. the change of magnitude of volatility spillovers under different regimes. This is captured by the coefficients $\gamma_{i,R}$ in Equation 5.1, where $R \in [I, II, III, IV]$. Table 5.5 shows that all the coefficients of $\gamma_{i,R}$ are highly significant at 1% level. The default regime is regime IV (i.e. $\gamma_{i,IV} \equiv 1$), which is associated with high return and low volatility. For the UK, as regime IV is not detected in the last 16 years, the default regime is set to be regime II, which is another low volatility regime.

The empirical results in Panel D suggest that the magnitudes of volatility transmission are highly sensitive to the regime changes. For example, when the securitized real estate market in the US is in its crisis regime, i.e. Regime I, the volatility spillover is approximately 3 times larger than in its default regime. Similar evidence is discovered in other securitized real estate markets. Compared to their default regimes, the magnitudes of volatility transmission in regime I in the UK, Japan, Hong Kong, and Singapore are 2.42, 2.07, 3.15, and 4.78 times higher, respectively. In regime III, the return goes up and the volatility increases as well, indicating an unstable period when the market has not reached the real bull market. For example, when the REIT market in the US reaches regime III, the volatility spillover magnitude increases by 3.25 times. From the empirical evidence in Hong Kong and Singapore, the volatility spillover magnitude in regime II is about half of the size in regime I, whereas it remains at a high level which is nearly two times the size in the default regime. The significant estimation result for the difference in magnitudes of volatility transmission under different regimes provides important empirical implications for international investors to adjust their expectations on the market comovements under different market environments.

From Panel E of Table 5.5, the hypothesis of $\rho_{ij} = 0$ and $\phi_{ij} = 1$ can be rejected for most i and j, $i \neq j$, which indicates that the estimated RDADC model is statistically different from other GARCH models. For example, the conditions (i) and (iv) are rejected, indicating that the VECH, BEKK, and asymmetric FARCH models are not able to reflect the additional information that was captured in the RDADC model. Furthermore, the hypothesis of $\phi_{ij} = 0$ is also rejected, indicating that there exists an asymmetry in the covariances that is not driven by the asymmetry in the variances, which can only be captured by the RDADC model.

The residual based diagnostic tests for the RDADC model is given in Table 5.6. Similar to the diagnostic results for GDC model, the squared residuals show no evidence of autocorrelation, indicating that the model has successfully filtered the autocorrelation in volatility. This can be reconfirmed in the ARCH LM test for the ARCH effect. There is still some serial correlation in the level of residuals from the US and Japan, which is probably due to the short VAR lag in the mean equation, but will not affect the power of the model.

Table 5.6 Diagnostic Statistics of the RDADC Model

	US	**UK**	**JP**	**HK**	**SG**
Ljung-Box statistic for up to 6 and 12 lags					
Q(6) for z_i	13.41**	16.25**	11.41	11.16	5.92
Q(12) for z_i	28.39**	21.86**	14.05	16.12	23.22**
Q(6) for z_i^2	4.75	4.46	7.80	1.12	11.07
Q(12) for z_i^2	16.99	13.63	15.40	1.97	14.56
ARCH LM test					
4 lags	1.18	1.81	1.72	0.32	2.26
8 lags	1.20	1.03	1.63	0.34	1.47
12 lags	1.34	1.44	1.63	0.26	1.24

Note:

Data in percentage.

** Significant at 5% level;

[a] Kolmogorov-Smirnov test for normality.

The high significance of the coefficients of asymmetric effects and regime change effects in Panel C and D of Table 5.5 has already demonstrated that RDADC model captures more information than the benchmark GDC model. Comparing Table 5.6 with Table 5.4, the diagnostic results have also verified that the RDADC model is more efficient than the benchmark GDC model in modeling volatilities. Therefore, incorporating the asymmetric effects and the regime change effects will improve the model accuracy and the understanding of multidirectional return and volatility transmissions.

5.5 Implications

The implications of the RDADC model will be discussed in this section. As a model intended to capture and model the short-term volatility spillovers, it is quite natural to use the estimated coefficients to draw the news impact surface (NIS) to illustrate the short-term asymmetric volatility spillover effects and correlation dynamics.

5.5.1 News Impact Surface

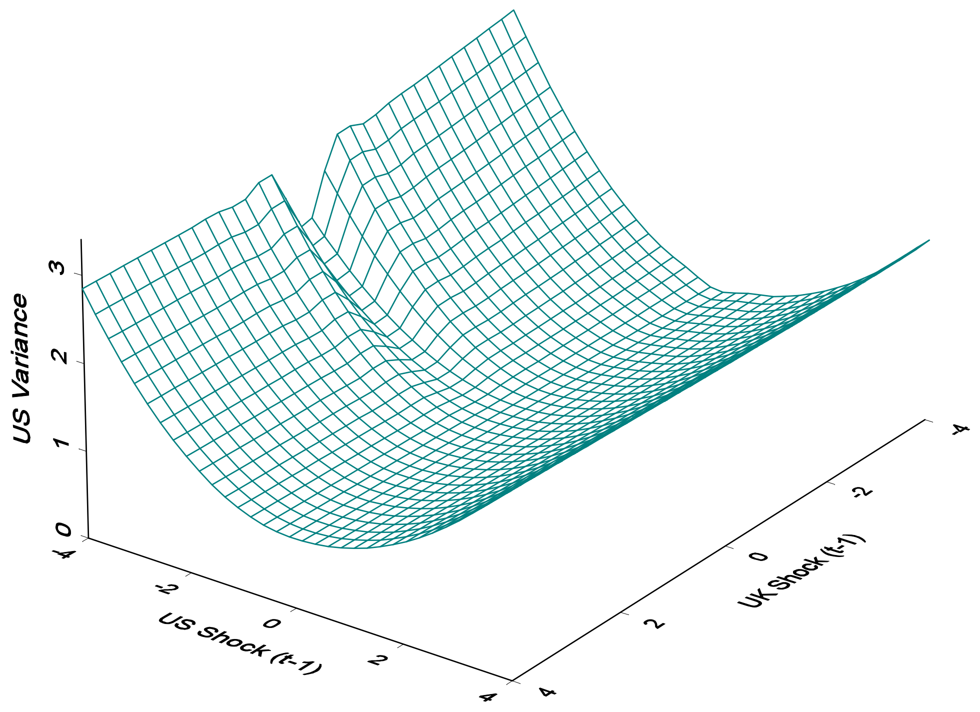
In Table 5.5, there are four pairs of countries that have both significant volatility spillover effect and the asymmetric effect: US and UK, UK and Singapore, Japan and Hong Kong, and Hong Kong and Singapore. For US and Singapore, no asymmetry is detected but the volatility spillover exists without asymmetric effect. The news impact surface for both variances and covariances are plotted in Figure 5.2 for the volatility transmission between these countries.

The news impact surface illustrates the change of conditional volatilities, covariances and correlations corresponding to the previous innovation impact (shock) in different countries. For each panel, figure (a) and (b) illustrate the change in conditional variance of returns in each country in response to the shocks (innovations) in the previous time period. The news impact surfaces for the conditional covariance and correlation are plotted in figure (c) and (d). For a significant volatility spillover effect with the asymmetries, like the US and the UK, we are able to see that the resulting change in volatilities, covariances and correlations are not symmetric to the zero impact surface of $US\ Shock\,(t-1)=0$ and $UK\ Shock\,(t-1)=0$. The changes after negative shocks are much larger than from positive ones. In contrast, there is no asymmetry detected in the spillovers between US and Singapore, resulting in a symmetric image in panel 2, in which the negative shocks have the same influence with the positive ones.

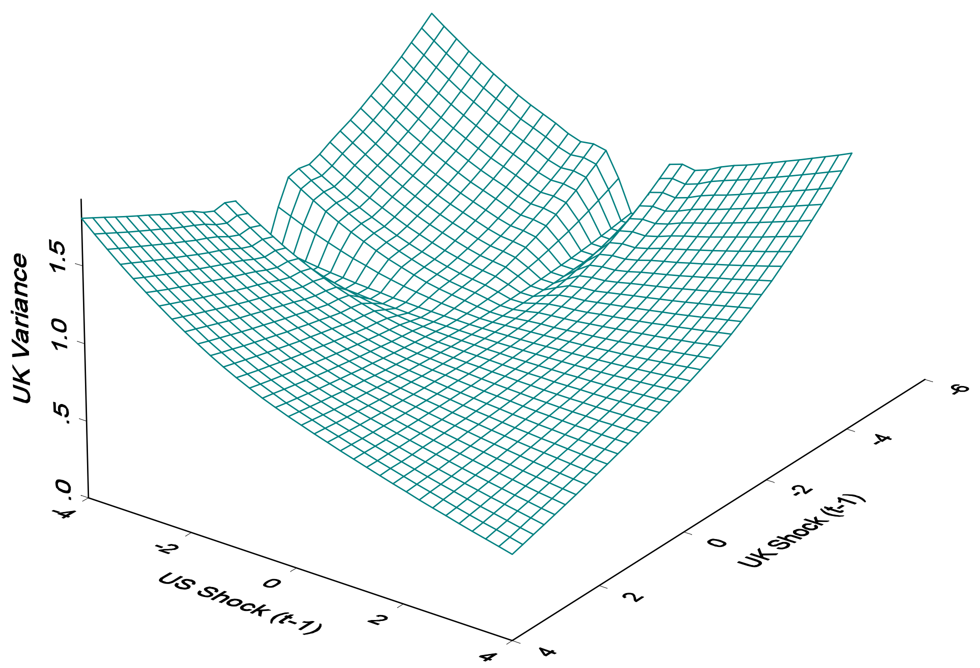
For the asymmetric effect, it is also observed that there is a deep increase near the zero impact surfaces in the negative partition, indicating that the asymmetric volatility transmission pattern is highly nonlinear and the increase margin usually declines after certain deviation from zero. Furthermore, although such sharp increase exists in both sides of the zero impact surfaces, the magnitude of the increase resulting from the negative shocks are still larger than positive ones. The correlations increase sharply when the lagged residual return is negative and large in absolute term, which is correspondent to the observation made in Longin and Solnik (1998) who find a similar relationship for monthly returns using extreme value theory.

Figure 5.2 News Impact Surfaces for conditional measures

Panel 1: US and UK

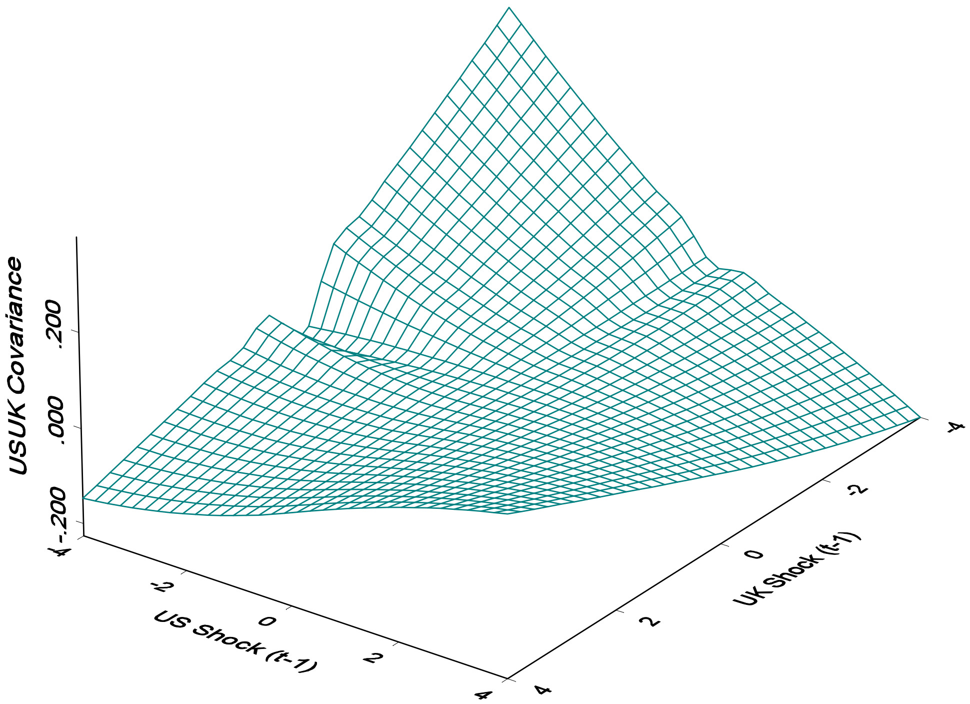


1(a)

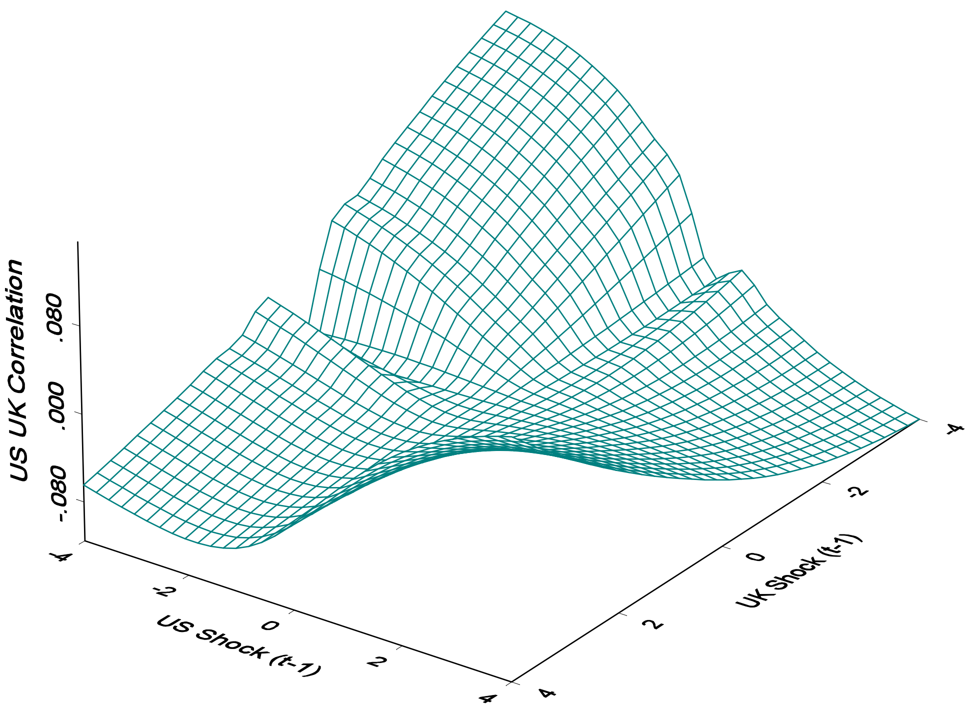


1(b)

Panel 1: US and UK (Continued)

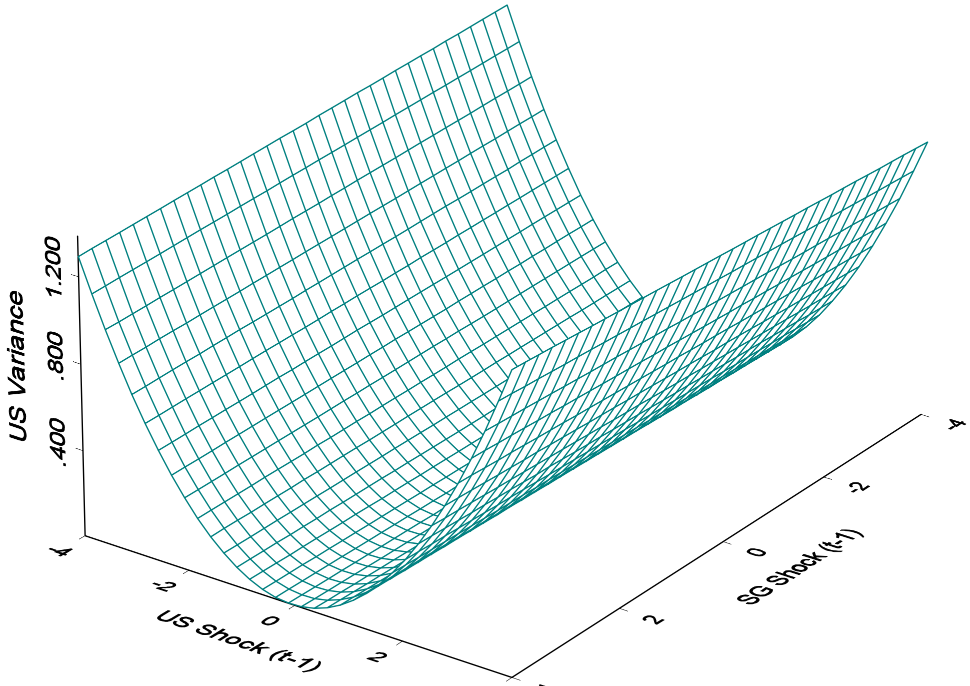


1(c)

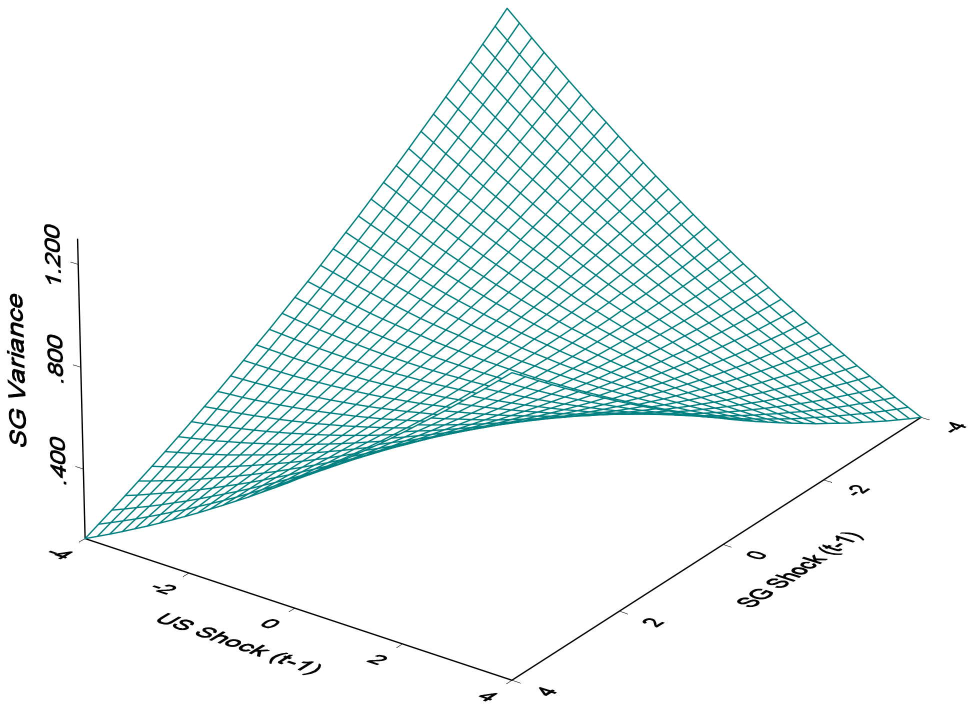


1(d)

Panel 2: US and SG

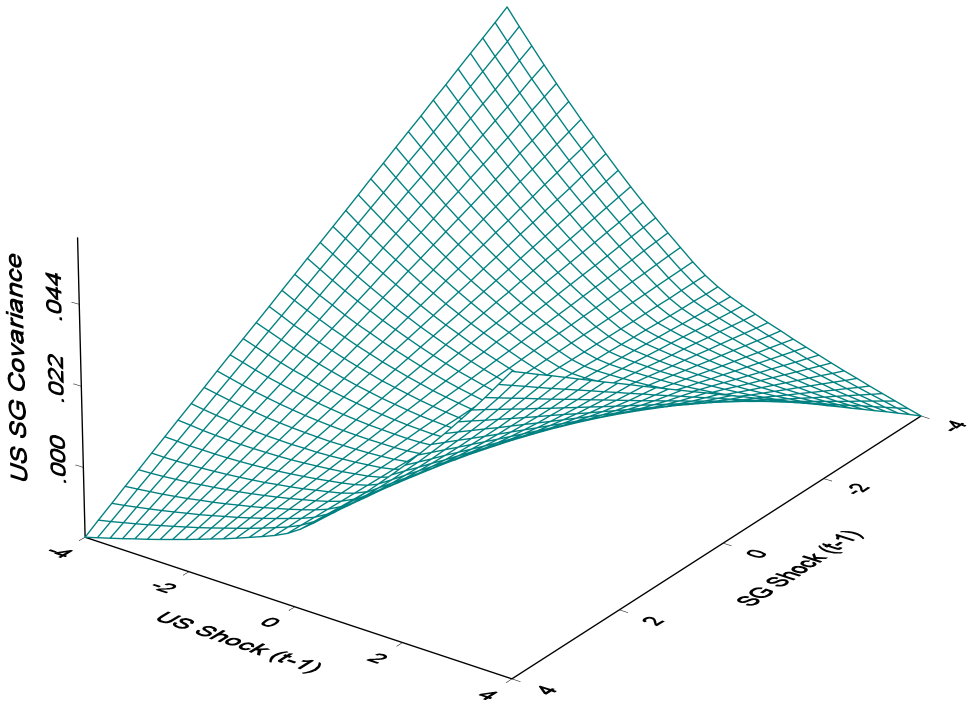


2(a)

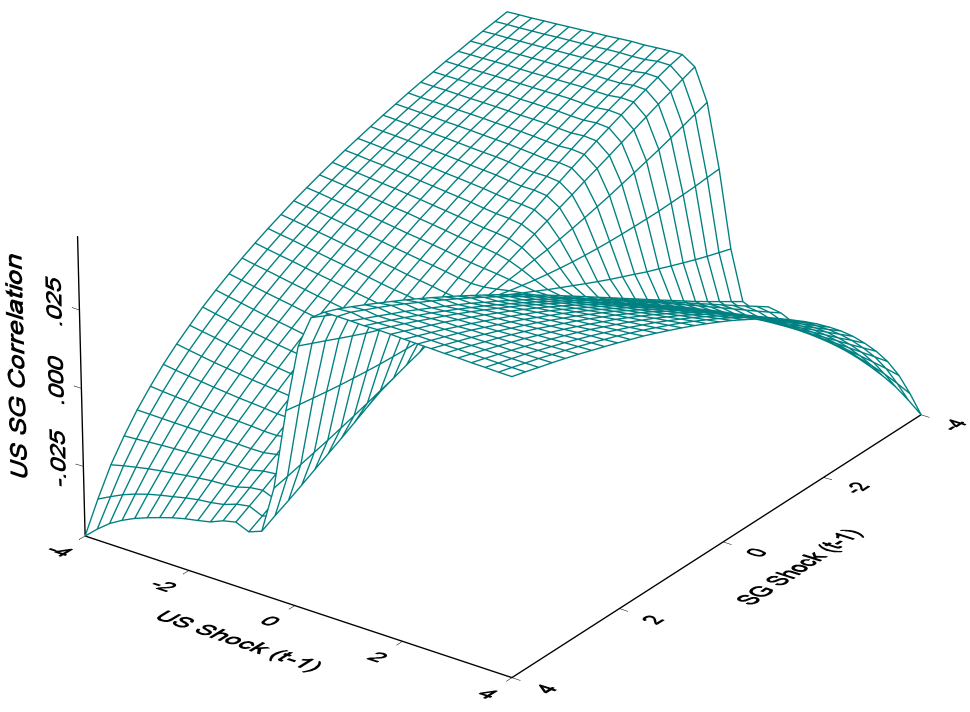


2(b)

Panel 2: US and SG (Continued)

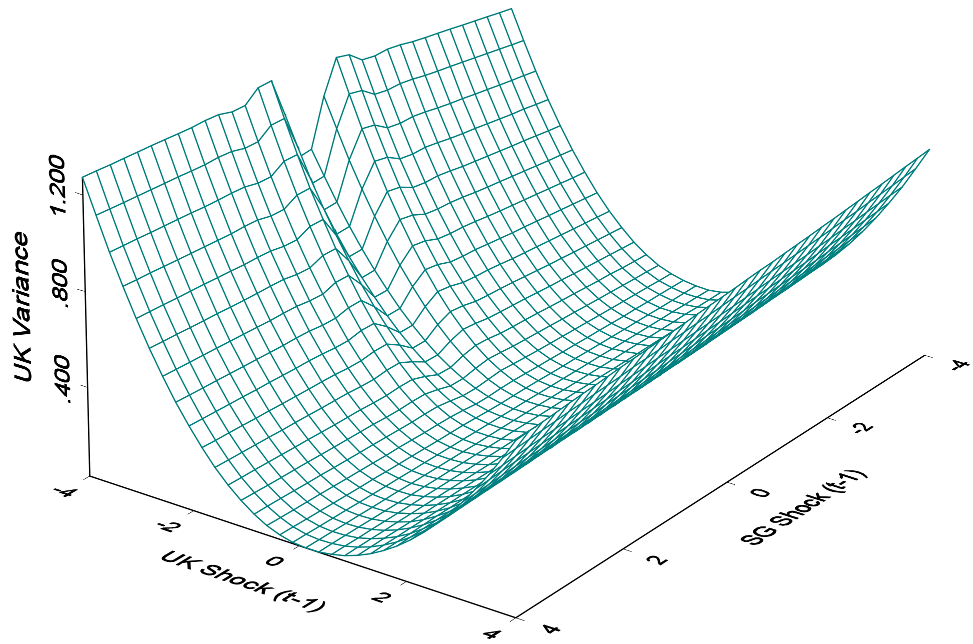


2(c)

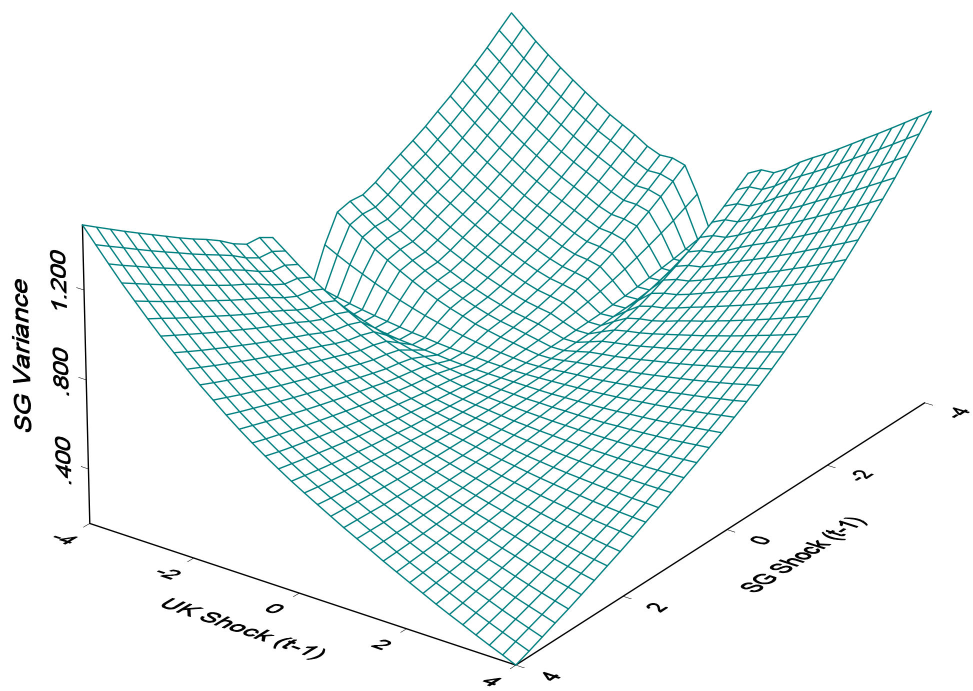


2(d)

Panel 3: UK and SG

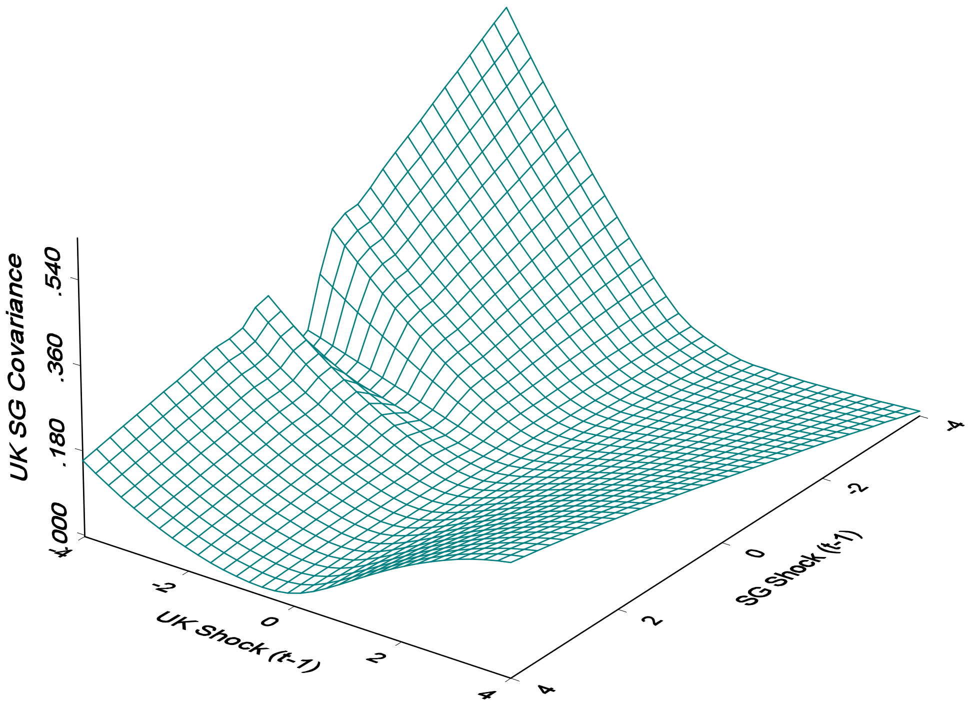


3(a)

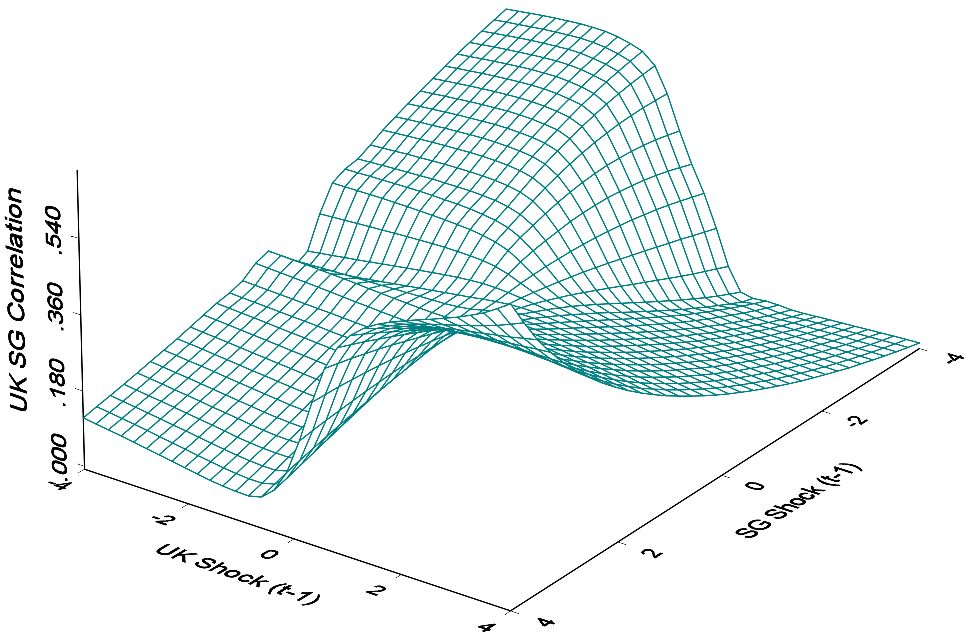


3(b)

Panel 3: UK and SG (Continued)

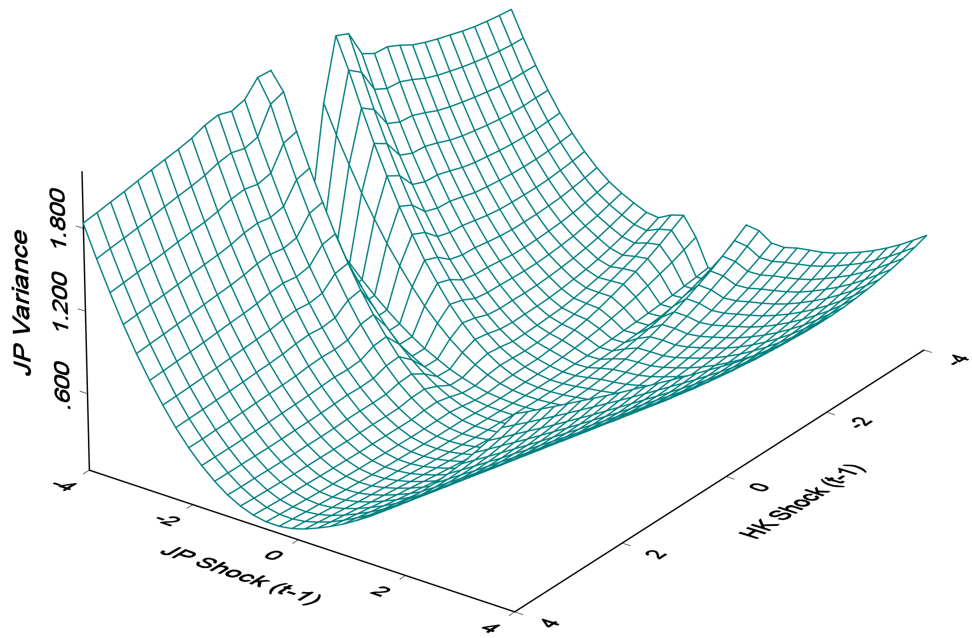


3(c)

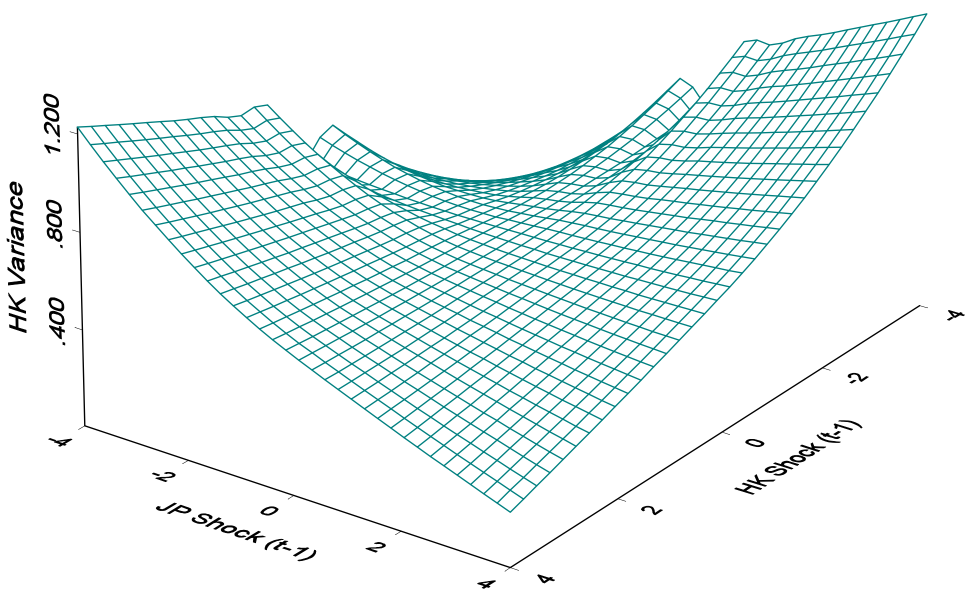


3(d)

Panel 4: JP and HK

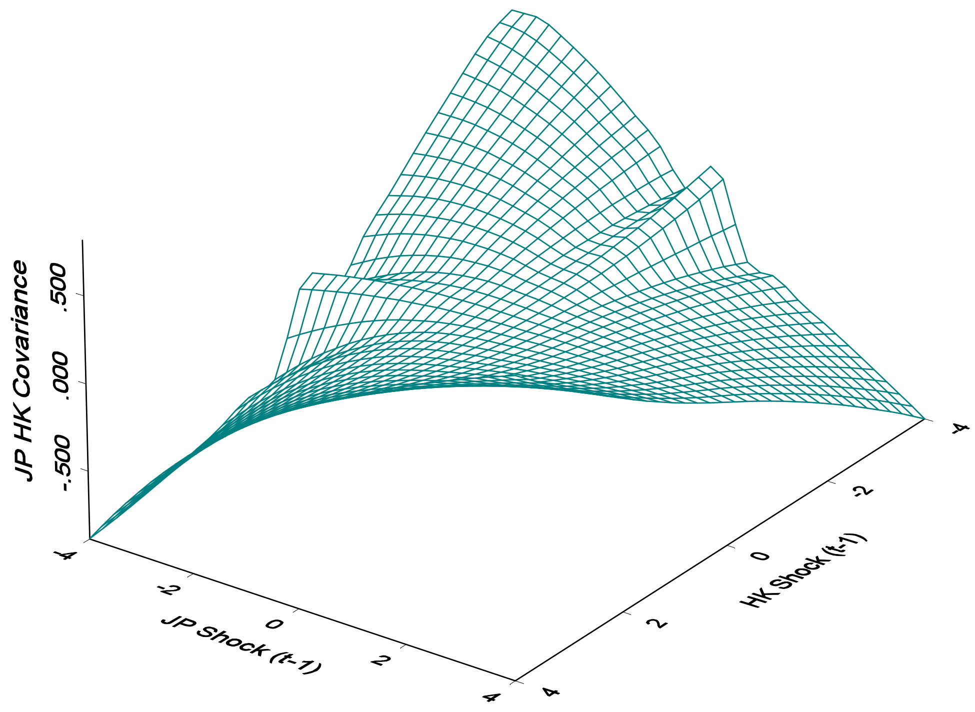


4(a)

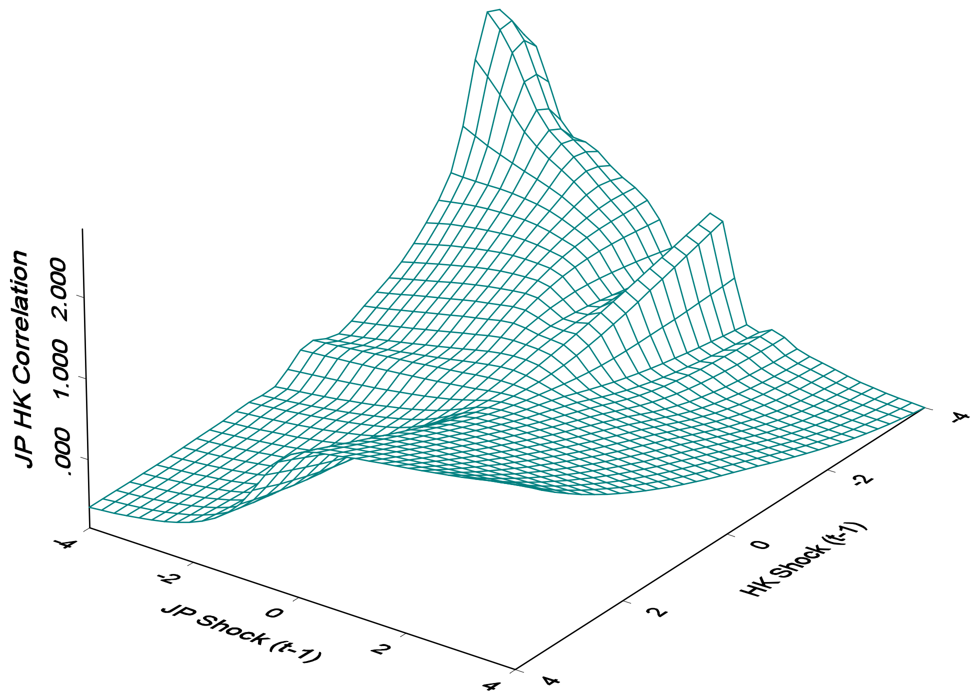


4(b)

Panel 4: JP and HK (Continued)

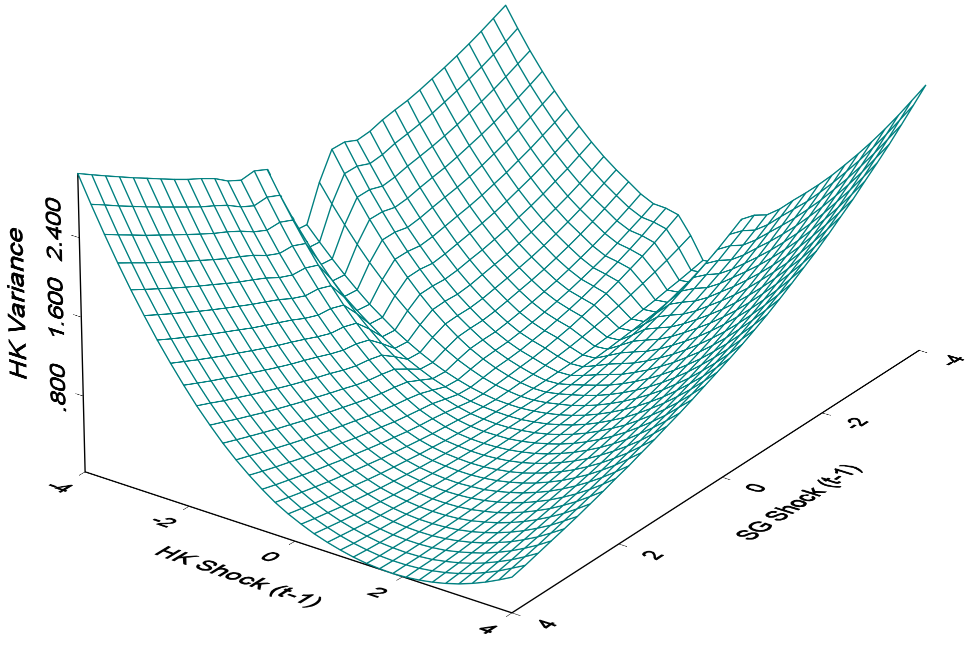


4(c)

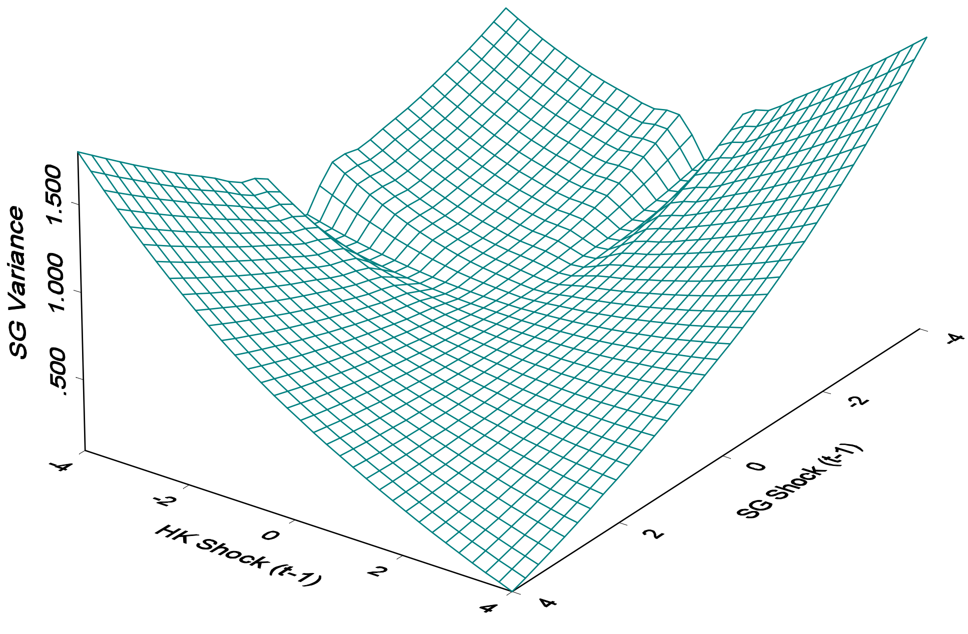


4(d)

Panel 5: HK and SG

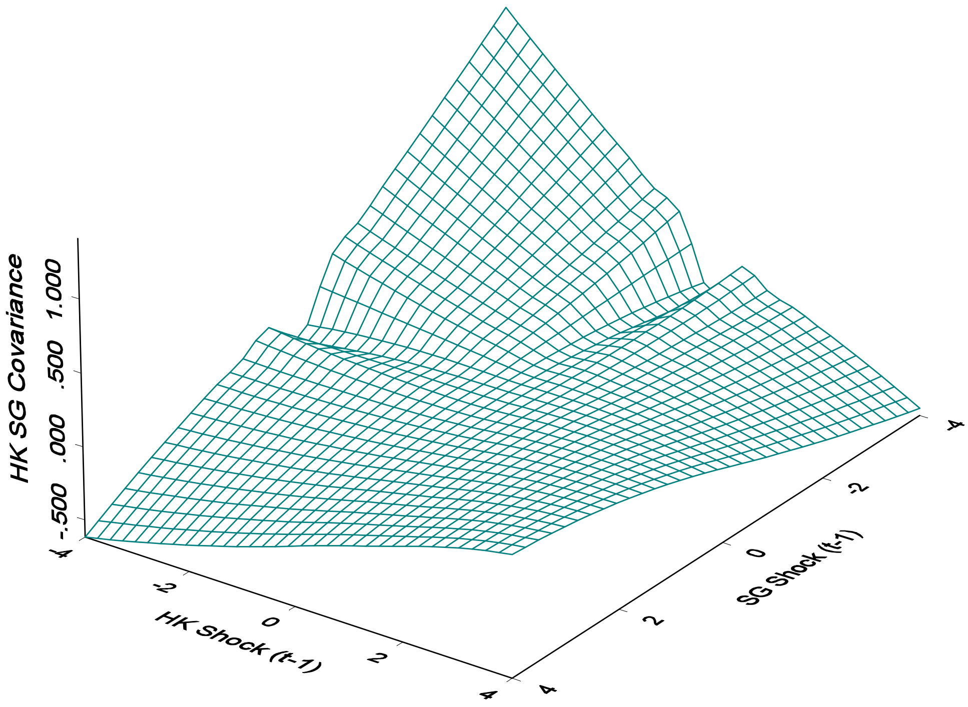


5(a)

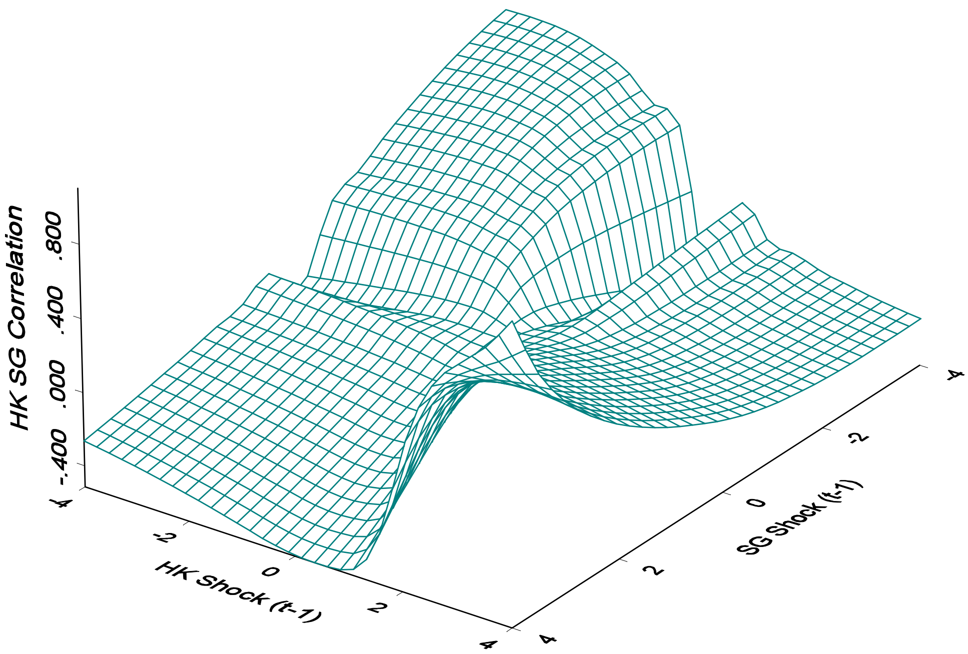


5(b)

Panel 5: HK and SG (Continued)



5(c)



5(d)

For international portfolio managers, the news impact surface is very helpful in determining the short-term comovements in the international securitized real estate markets. For instance, in those the symmetric spillover pattern, such as the one between the US and Singapore, whether the markets are under pressure or not does not influence the volatility transmissions, indicating possible hedging benefits in these two markets. It is also observed that the correlations between international securitized real estate markets usually has little response with lagged innovations within the midrange from -1% to 1%.

5.5.2 Risk-minimizing Portfolio Weights

According to Kroner and Ng (1998), estimating the right time-varying covariance matrix is essential for asset pricing, portfolio selection, and risk management. To illustrate the importance of the covariance matrix to these types of financial problems, the empirical results from the estimation of the RDADC model are employed to construct the risk-minimizing portfolio weights.

Consider the problem of calculating the optimal fully invested portfolio holdings subject to a no-shorting constraint. This application is usually faced by portfolio managers when deriving their optimal portfolio holdings. Supposed a portfolio manager is interested in investing in two securitized real estate markets, country 1 ($C1$) and country 2 ($C2$), without any short selling permitted. Define

$$\zeta = \frac{h_{22,t} - h_{12,t}}{h_{11,t} - 2h_{12,t} + h_{22,t}}$$

Assuming a mean-variance utility function, the optimal portfolio holdings of the securitized real estate markets in country 2 are

$$\zeta^* = \begin{cases} 0, & if \quad \zeta_t < 0 \\ \zeta_t, & if \quad 0 \le \zeta_t \le 1 \\ 1, & if \quad \zeta_t > 1 \end{cases}$$

and the optimal holdings of the securitized real estate markets in country 1 are $1-\zeta^*$. The empirical results of the risk-minimizing portfolio weights are shown in Table 5.7.

Table 5.7 Optimal Fully Invested Portfolio Weights

		Country 2				
		US	**UK**	**JP**	**HK**	**SG**
Country 1	**US**	1.000				
	UK	0.690	1.000			
	JP	0.891	0.827	1.000		
	HK	0.848	0.728	0.371	1.000	
	SG	0.854	0.741	0.405	0.550	1.000

Note:
The weights in the table are the optimal risk minimizing portfolio weights in country 2 in a fully invested, no-shorting portfolio.

As shown in Table 5.7, when a portfolio manager considers investing in the securitized real estate markets in US and UK, he will probably achieve a risk minimizing portfolio if he invests 69% of his wealth in US. It seems that the US REIT market always takes a large weight when compared to other securitized real estate markets, ranging from 69% to 89%. UK plays a similar role when compared to the Asian markets, with a weight in UK from 72% to 82%. Japan seems not that favorable to those investors seeking a minimum risk in their portfolios, even compared to other Asian markets, like Hong Kong and Singapore. The performances of the securitized real estate markets in Hong Kong and Singapore are quite similar, as expected. The optimum weight for Hong Kong is 55%, which is slightly larger than Singapore.

Table 5.8 Optimal Fully Invested Portfolio Weights in different Regimes

			Country 2											
	Regime		**US**			**UK**			**JP**			**HK**		
			I	**III**	**IV**	**I**	**II**	**III**	**I**	**III**	**IV**	**I**	**II**	**IV**
Country 1	**UK**	**I**			0.807									
		II	0.577		0.779									
		III	0.647	0.577										
	JP	**I**	0.935		0.915	0.762	0.936							
		III	0.891				0.905	0.850						
		IV	0.939	0.753	0.926	0.646	0.848	0.737						
	HK	**I**	0.925		0.983		0.918		0.434		0.520			
		II	0.861				0.856	0.771	0.418	0.380				
		IV		0.643	0.872	0.539	0.770	0.585	0.257		0.383			
	SG	**I**	0.958		0.988		0.956		0.496		0.628	0.706	0.600	
		II	0.895				0.890	0.831	0.564	0.456			0.612	
		IV		0.632	0.869	0.542	0.776	0.582	0.279		0.369	0.318	0.489	0.495

Note:

The weights in the table are the optimal risk minimizing portfolio weights in country 2;

Some regimes are not observed in the sample period so that they are left blank.

The above results are based on the empirical estimates for the whole sample period from 1990 to 2006. It is expected that the portfolio weights will vary across different regimes as the volatility changes. Therefore, the optimum risk-minimizing portfolio weights for different regimes are also calculated. The results are reported in Table 5.8.

As the risk-minimizing portfolio weight only depends on the volatility of each market, the portfolio weights for one country in the high volatility regimes, namely regime I and regime III, are less than in the low volatility regimes. For example, when the UK is in regime II, a shift from regime I to regime IV in the US market will increase the optimum portfolio weight invested in US from 57.7% to 77.9%. Once the regime of the market is determined, Table 5.8 will provide useful historical evidence for the risk-minimizing investments under each regime, which is essential to portfolio managers.

5.5.3 Optimal Hedge Ratio (OHR)

When investors participate in two markets, they must choose a hedging strategy that reflects their individual goals and attitudes towards risk. For example, consider an investor with a long position of $100 in US REIT market who wishes to hedge some proportion of this long position in the securitized real estate market in UK. The return on the investor's portfolio of the securitized real estate market in UK and US REIT market can be denoted by

$$R_t = R_t^{US} - \beta_{t-1} R_t^{UK}$$

where R_t is the return on holding the portfolio between $t-1$ and t; R_t^{US} is the return on holding the portfolio in US REIT market, and R_t^{UK} is the return from investing in UK market. β_{t-1} is the hedge ratio. The variance of the return on the hedged portfolio, conditional on information available at time $t-1$, is given by

$$Var(R_t \left| \Omega_{t-1}) = Var(R_t^{US} \right| \Omega_{t-1}) + \beta_{t-1}^2 Var(R_t^{UK} \left| \Omega_{t-1}) - 2\beta_{t-1} Cov(R_t^{US}, R_t^{UK} \right| \Omega_{t-1})$$

An optimal hedge ratio (OHR) is defined as the value of β_{t-1} which minimizes the conditional variance of the hedge portfolio return, and can be expressed as:

$$\beta_{t-1} = Cov(R_t^{US}, R_t^{UK}, \left| \Omega_{t-1}) / Var(R_t^{UK} \right| \Omega_{t-1})$$

The objective of variance minimization assumes a high degree of risk aversion. However, it can be shown that, provided expected returns to hold the securitized real assets in the UK are zero, the minimum variance hedging rule is also generally the expected utility-maximizing hedging rule. This makes the simple minimum variance hedging rule much more widely applicable than is generally recognized. A proof of this result is available in Baillie and Myers (1989), and is related to a similar result obtained by Benninga et al. (1984).

Most early studies on optimal hedge ratio assume that the conditional covariance matrix is constant over time, such as Ederington (1979), Anderson and Danthine (1981) and Hill and Schneeweis (1981). As a result, the OHR is also constant and can be obtained as the slope coefficient of a regression of the change in the return in one market on the change in the return in the other market. However, it is clear that optimal hedge ratios depend on the conditional distribution of market price movements, and that hedge ratios will almost certainly vary over time as this conditional distribution changes. In the later studies, GARCH model is widely used to generate time-varying conditional variances and covariances. For example, Cecchetti et al. (1988) allow for time-varying optimal hedge ratios using an ARCH model to represent time variation in the conditional covariance matrix of Treasury bond returns and bond futures. They found substantial time variation in the optimal hedge ratio series. Some other literature has also investigated the issue of the optimal hedge ratio. For example, Kroner and Claessens (1991) and Kroner and Sultan (1993) use the multivariate Constant Correlation (CC) model, and Baillie and Myers (1991) use the VECH model.

In this case, however, there are some information that has been captured by the RDADC model that are not likely to be captured in other multivariate GARCH models, because of the more generalized feature of RDADC model that nests other multivariate models together. As a result, it is essential to use the RDADC model to construct the risk-minimizing hedge ratios for international securitized real estate markets.

The empirical results of the risk-minimizing optimal hedge ratio for the international securitized real estate markets are plotted in Figure 5.3. The time-varying conditional covariance matrix is obtained from the results of the RDADC model. Constant OHRs, estimated via conventional regression methods, are also plotted on the figures for purposes of comparison (as dotted lines). Strikingly enough, all plots show considerable variation in the optimal hedge ratio over time, and none appears consistent with a constant hedge ratio. Further tests also show that all OHRs are actually nonstationary, and highly autocorrelated. The averages of the time-varying OHRs are summarized in Table 5.9 for comparison across markets.

Table 5.9 Optimal Risk-Minimizing Hedge Ratio

		Country 2				
		US	**UK**	**JP**	**HK**	**SG**
Country 1	**US**	1.000	0.167	0.155	0.292	0.261
	UK	0.079	1.000	0.337	0.265	0.286
	JP	0.016	0.083	1.000	0.155	0.162
	HK	0.048	0.097	0.246	1.000	0.418
	SG	0.038	0.092	0.225	0.366	1.000

Note:
The figures in the table are the optimal risk minimizing hedge ratios. A hedge ratio of 0.36 means that the investor would short $36 worth of the portfolio in country 1 to hedge against a long position of $100 in country 2.

Figure 5.3 The Optimum Hedge Ratios in International Securitized Real Estate Markets

Panel 1: Hedge Ratios against US **Panel 2: Hedge Ratios against UK**

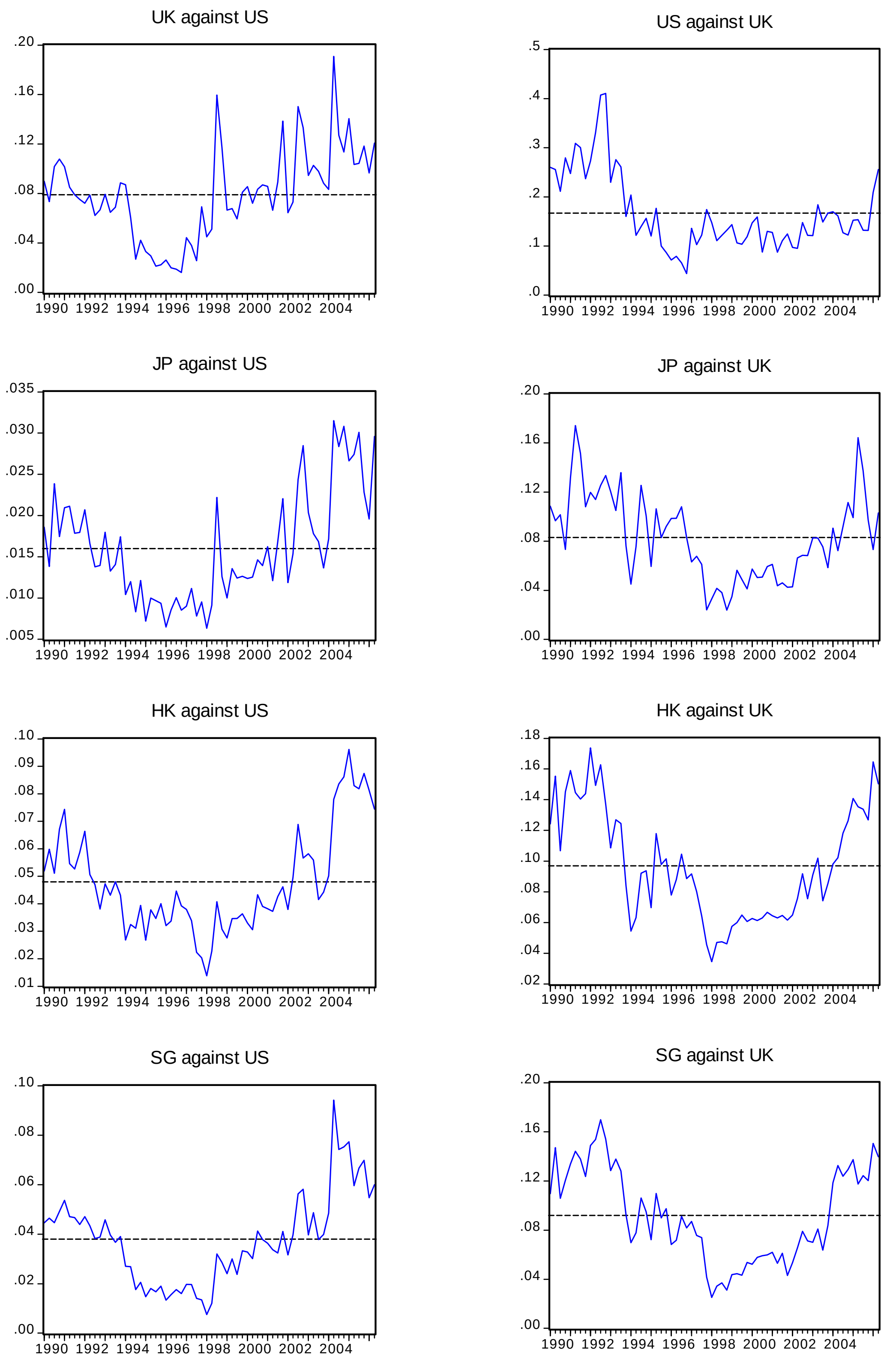
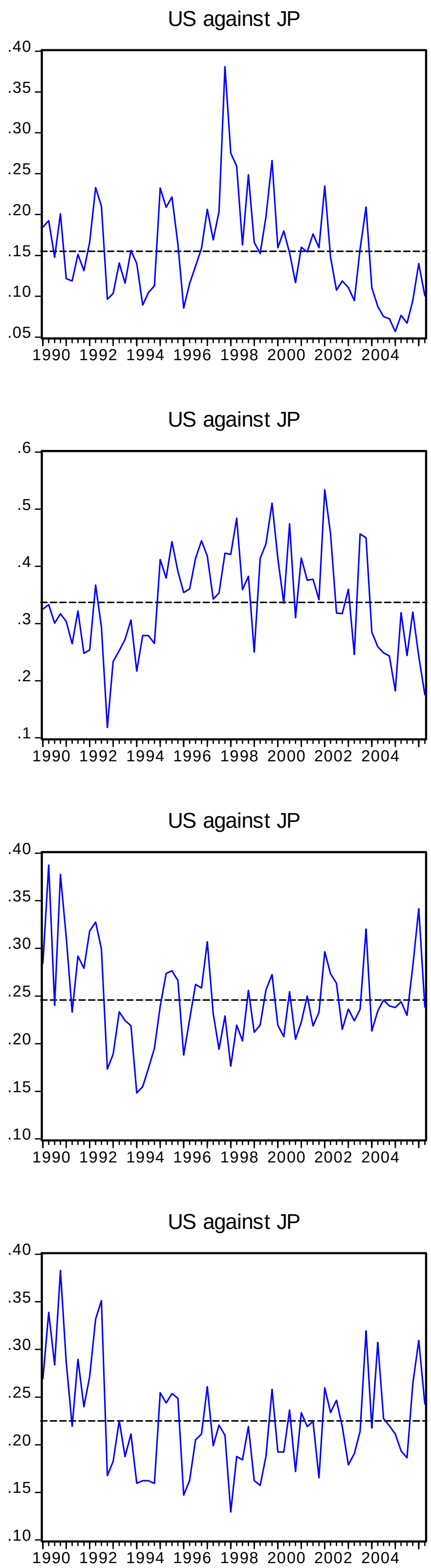


Figure 5.3 The Optimum Hedge Ratios in International Securitized Real Estate Markets (Continued)

Panel 3: Hedge Ratios against JP



Panel 4: Hedge Ratios against HK

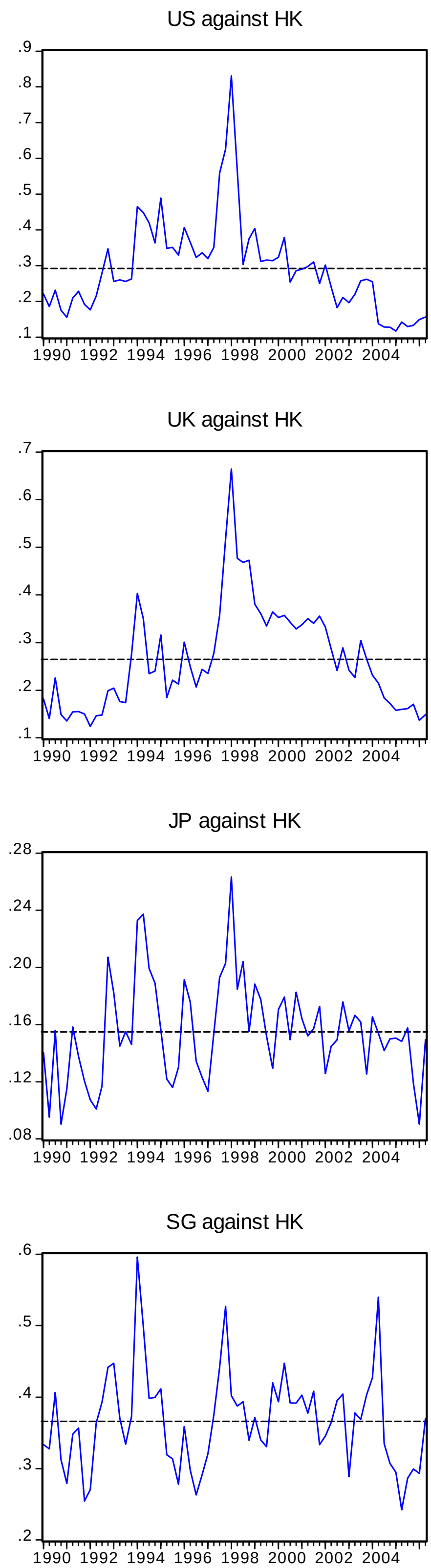
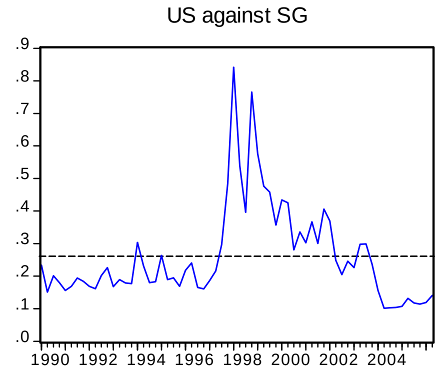
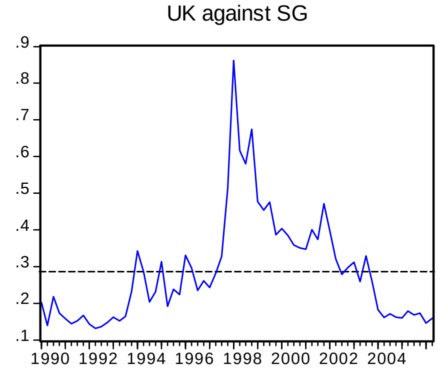
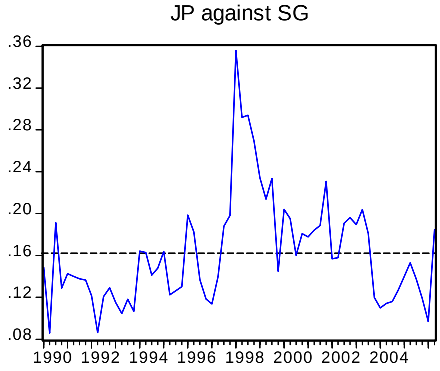


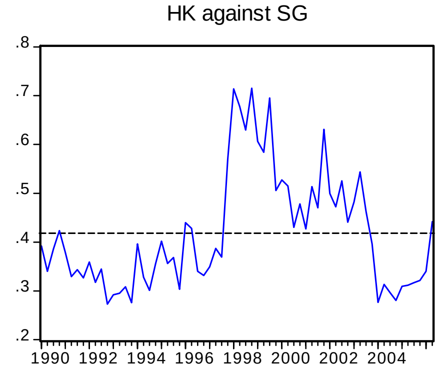
Figure 5.3 The Optimum Hedge Ratios in International Securitized Real Estate Markets (Continued)

Panel 5: Hedge Ratios against SG









5.6 Summary

The second part of empirical investigation of short-term return and volatility linkages in five securitized real estate markets is presented in this chapter. The major findings can be summarized as follows:

(a) The Regime-dependent Asymmetric Dynamic Covariance (RDADC) model is a general and robust model in estimating the short-term lead/lag interactions and comovements under different market regimes in the international securitized real estate markets. Furthermore, the substantial evidence suggests that the use of other multivariate GARCH models will fail to capture some information that is well filtered in the RDADC model, such as the covariance asymmetry that is not driven by the asymmetries in variances;

(b) Several significant transmissions in returns across geographic borders are detected in the RDADC model. The US REIT market is regarded as the most influential market in terms of the return spillovers, suggesting that all other securitized real estate markets are sensitive to the change of returns in the US market;

(c) Volatility spillovers are well captured by the RDADC model as well. There are multidirectional transmissions of the past innovations among international securitized real estate markets. Asymmetric effects are detected in most countries, suggesting that the negative innovations are more influential than positive ones. Furthermore, the scale parameters, which reflect the magnitude of the increase in volatility spillovers under high volatility regimes, are highly significant, indicating the importance of taking into consideration of the volatility regime changes. This can also be reconfirmed by the comparison of the diagnostic results of the RDADC model and the benchmark GDC model;

(d) Finally the application of the short-term study is discussed. The empirical results are important for global investors and portfolio managers to understand the short-term market comovements, to determine the optimal risk-minimizing portfolio weights and to calculate the optimal hedge ratios against the objective markets.

Chapter 6
Conclusion

6.1 Summary of main findings

This study investigates the long-run relationships and short-term linkages in international securitized real estate markets with the consideration of structural breaks and heteroskedasticity. The major findings can be summarized as follows.

The securitized real estate market has grown rapidly in the last few decades in the world and is now becoming more and more prevalent as a means of investment in real estate industry. Descriptive statistics demonstrated that Asian securitized real estate markets are more volatile than the US and UK. Further evidence shows that both long-run relationships and short-term linkages are stronger within Asian markets.

Significant structural breaks in both price and volatility indices are detected in each securitized real estate market. Most of the significant break points in prices occurred around year 1996 and 1997, which is consistent with the outburst of Asian financial crisis and the internet and high-tech bubble.

According to the unit root test results, all the price indices in these markets are non stationary over the sample period. Both parametric and non-parametric cointegration tests show that there is no long-run relationship in international securitized real estate markets before 1997; whereas significant cointegration relation is confirmed after such break. Therefore, failure to take into account the possible structural breaks will lead to erroneous conclusions about the long-run relationships.

Four volatility regime types are defined, which occur in sequence to form a market cycle in all securitized real estate markets. The Regime-dependent Asymmetric Dynamic Covariance (RDADC) model is a general and robust model in estimating the short-term linkages in the markets under different volatility regimes. Several significant transmissions in both returns and volatilities across geographic borders are detected in the RDADC model. The US REIT market is regarded as the most influential market in terms of the return spillovers. Multidirectional transmissions of the volatilities are detected in the model as well. Furthermore, the scale parameters for regime switches are highly significant, indicating the importance of the consideration of volatility regime changes.

6.2 Implications of the research

The findings in this research provide valuable insights to academic researchers and professional investors in international securitized real estate markets.

First, the present of multiple structural breaks raises a caution for researchers who are trying to investigate international securitized real estate markets. Failure to take into consideration of structural breaks will lead to erroneous results, because the estimates will probably not be consistent over time. The four volatility regime types defined is useful for investors to compare the current market conditions with the historical experience, which is important in understanding the market behavior and helpful to the risk management.

Second, the significant impact of structural breaks on long-run cointegration relations suggests that the benefits of international diversification might vary with the diverse risk-return characteristics under different market environments. Specifically, the increasing cointegration relation between these five securitized real estate markets indicates that the benefits of international diversification in these markets have been reduced in the last decade. The possible explanation is, with the deregulation of emerging markets and the growing size of market capitalization and investors, the securitized real estate markets act more and more like the stock markets, thus becoming more cointegrated with each other, which eliminates the diversification benefits.

Third, the significant impact of the structural breaks on the short-term market spillovers also suggests that the magnitude of the volatility transmission from one market to others is highly sensitive to the market environments. The investors would be wise to identify the current market regimes and keep in mind the abnormal magnitudes of market comovements under certain regimes.

Finally, the coefficient estimates and the conditional variance/covariance series derived from the RDADC model are very useful for investors and portfolio managers to understand the short-term market comovements, to determine the optimal risk-minimizing portfolio weights and to calculate the optimal hedge ratios against the objective markets. For example, the historical optimal portfolio weights under different market regimes, as shown in Table 5.8 in Chapter 5, provide important reference information for international portfolio managers in making asset allocating strategies. The time-varying optimal hedging ratios also have insightful implications for international investment in the securitized real estate markets.

6.3 Limitations and Recommendations

Admittedly, there are some limitations in this research. Firstly, as a study on international markets, one inherent limitation is the data. This study only focused on the major securitized real estate markets including the US, the UK, Japan, Hong Kong and Singapore. The span of the sample period is subject to data availability so that only past 16 years are examined. Further studies might include more European countries and examine a longer time period.

Secondly, this research only focused on the international securitized real estate markets. However, global investors usually seek for diversification benefits across different asset classes. Further studies might include other assets, such as direct real estate, stocks and bonds, to achieve a more comprehensive understanding of global mixed-asset investment.

Thirdly, the multiple structural breaks in volatilities have already indicated a possible cyclical effect in international securitized real estate markets. Further studies may extend the data set and make this image clearer and further relate it to the studies on business cycles.

Lastly, further studies can also try to utilize the ex post estimations in the short-term lead/lag return and volatility spillover models to develop a trading strategy in international markets, which will certainly generate other profound results.

Bibliography

[1] Addae-Dapaah, K. and C. Kion, 1996, International diversification of property stock: A Singaporean investor's viewpoint, *The Real Estate Finance Journal*, 13, 3, 54–66

[2] Amberlamb, *Property Investment Guide*, for Hong Kong property market and Singapore property market,

[3] Anderson, R.W., and J.P. Danthine, 1981, Cross hedging, *Journal of Political Economy*, 81, 1181-1196

[4] Andrews, D.W.K., I. Lee, and W. Ploberger, 1996, Optimal changepoint tests for normal linear regression, *Journal of Econometrics*, 70: 9-38

[5] Ang, A., and G. Bekaert, 2002, International Asset Allocation with Regime Shifts, *Review of Financial Studies*, 15, 4, 1137-1187

[6] Aquino, R.Q., 2005, Exchange rate risk and Philippine stock returns: before and after Asian financial crises, Applied Financial Economics, 15, 765-771

[7] Asabere, P.K., R.T. Kleiman and C.B. McGowan, Jr. 1991. The risk-return attributes of international real estate equities. *Journal of Real Estate Research*, 6(2): 143–152

[8] Bai, J., and P. Perron, 1998, Estimating and testing linear models with multiple structural changes, *Econometrica*, 66, 47-68

[9] Bai, J., and P. Perron, 2003a, Computation and analysis of multiple structural change models, *Journal of Applied Econometrics*, 18, 1-22

[10] Bai, J., and P. Perron, 2003b, Critical values in multiple structural change tests, *Econometrics Journal*, 6, 72-78

[11] Bai, J., and P. Perron, 2004, Multiple structural change models: A simulation study, in Corbea D., Durlauf S., and Hansen B.E., eds.: *Econometrics Essays* (Cambridge University Press, Cambridge, England)

[12] Bala L., and G. Premaratne, 2003, Stock Market Volatility: Examining North America, Europe and Asia, *Working Paper*

[13] Bailey, W., and R.M. Stultz, 1990, Benefits of international diversification: the case of pacific basin stock markets, *The Journal of Portfolio Management*, 16, 4, 57-61

[14] Baillie, R.T., and R.J. Myers, 1991, Bivariate GARCH estimation of the optimal

commodity futures hedge, *Journal of Applied Econometrics*, 6, 109-124

[15] Baillie R.T., and R.P. DeGennaro, 1990, Stock returns and volatility, *Journal of Financial and Quantitative Analysis*, 25, 203-214

[16] Barkham, R.J., and D.M. Geltner, 1995, Price discovery in the American and British property markets, *Real Estate Economics* 23(1), 21-44

[17] Barkham, R.J., and D.M. Geltner, 1996, Price discovery and efficiency in the UK housing market, *Journal of Housing Economics* 5, 41-63

[18] Barry, C., M. Rodriguez and J. Lipscomb, 1996, Diversification potential from real estate companies in emerging capital markets, *Journal of Real Estate Portfolio Management*, 2, 2, 107–118

[19] Baum, A.E., and A. Schofield, 1991, Property as a global asset. In: Venmore-Rowland, P., Mole, T., Brandon, P. (Eds.), Investment, Procurement and Performance in Construction, *Chapman and Hall*, 103-155

[20] Benninga, S., R. Eldor, and I. Zilcha, 1984, The optimal hedge ratio in unbiased futures markets, *Journal of Futures Markets*, 4, 155-159

[21] Bera, A.K., and M.L. Higgins, 1993, ARCH models: Properties, estimation and testing, *Journal of Economic Surveys*, 7, 4, 305-366

[22] Bertero, E. and C. Mayer, 1990, Structure and performance: Global interdependence of stock markets around the crash of October 1987, *European Economic Review*, December, 1155-80

[23] Bierens, H.J., 1997, Nonparametric cointegration analysis, *Journal of Econometrics*, 77, 379-404

[24] Bigman, T., 2002, Investing in international listed property companies, *PREA Quarterly*, Winter, 53–61

[25] Black, F., 1976, Studies of stock market volatility changes, 1976 *Proceedings of the American Statistical Association, Business and Economic Statistics Section*, 177-181

[26] Bollerslev, T., 1986, Generalized autoregressive conditional heteroskedasticity, *Journal of Econometrics*, 31, 309-328

[27] Bollerslev, T., 1990, Modelling the coherence in short-run nominal exchange rates: A multivariate Generalized ARCH approach, *Review of Economics and Statistics*, 72, 498-505

[28] Bollerslev T., R.Y. Chou, and K.F. Kroner, 1992, ARCH modeling in finance: A review of the theory and empirical evidence, Journal of Econometrics, 52, 5-59

[29] Bollerslev, T., R. Engle, and J. Wooldridge, 1988, A capital asset pricing model with time varying covariances, *Journal of Political Economy*, 96, 116-131

[30] Bollerslev, T., R.Y. Chou, and K.F. Kroner, 1992, ARCH modeling in finance: A selective review of the theory and empirical evidence, *Journal of Econometrics*, 52, 5-59

[31] Breitung, J., 2002, Nonparametric tests for unit roots and cointegration, *Journal of Econometrics*, 108, 343-363

[32] Brown, G.R., and G.A. Matsiak, 2000, Real Estate Investment: A Capital Market Approach, *Pearson Education Ltd.*

[33] Brunetti, C., and P. Lildholdt, 2002, Return-based and range-based (co)variance estimation – with an application to foreign exchange markets, *Mimeo*, University of Pennsylvania

[34] Brunetti, C., R.S. Mariano, C. Scotti and A.H.H. Tan, 2003, Markov switching GARCH models of currency crises in Southeast Asia, *PIER Working Papers*, 03-008

[35] Cai, J., 1994, A Markov model of unconditional variance in ARCH, *Journal of Business and Economic Statistics*, 12, 309-316

[36] Campbell, J.Y., and N.G. Mankiw, 1987, Permanent and transitory components in macroeconomic fluctuations, *American Economic Review*, 77, 111-117

[37] Case, B., W. Goetzmann, and K.G. Rouwenhorst, 2000, Global real estate markets –cycles and fundamentals, *NBER Working Paper Series*, Paper No. 7566

[38] Cecchetti, S.G., R.E. Cumby, and S. Figlewski, 1988, Estimation of optimal futures hedge, *Review of Economics and Statistics*, 70, 623-630

[39] Chaplin, R., 1997, Unsmoothing valuation based indices using multiple regimes, *Journal of Property Research* 14(3), 189-210

[40] Chau, K.W., B.D. MacGregor, and G.M. Schwann, 1999, Price discovery in the Hong Kong real estate market, *Aberdeen Papers in Land Economy*, 99-112

[41] Chaudhry, M.K., F.C.N. Myer and J.R. Webb, 1999, Stationarity and cointegration in systems with real estate and financial assets, *Journal of Real Estate Finance and Economics*, 18, 339-349

[42] Chaudhry, M.K., R.A.C. David, and W.H. Sackley, 1999, Long-term structural price relationships in real estate markets, *Journal of Real Estate Research*, 18, 2, 335

[43] Chen, Z.W., and K.H. Liow, 2006, Mean and volatility spillovers across major real estate markets, *Asset Pricing Section, 22nd American Real Estate Association Conference*, April, USA

[44] Chow, G.C., 1960, Tests of equality between sets of coefficients in two linear regressions, *Econometrica*, 28, 591-605

[45] Christiano, L.J., and M. Eichenbaum, 1989, Unit roots in real GNP: Do we know, and do we care? *Discussion paper 18*, Federal Reserve Bank of Minneapolis, Institute for Empirical Macroeconomics

[46] Christie, A.A., 1982, The stochastic behavior of common stock variances: value, leverage and interest rate effects, *Journal of Financial Economics*, Vol. 10, 407-432

[47] Clark, P.K., 1987, The cyclical component of U.S. economic activity, *Quarterly Journal of Economics*, 102, 797-814

[48] Cochrane, J.H., 1988, How big is the random walk in GNP?, *Journal of Political Economy*, 96, 893-920

[49] Conover, C., H. Friday and G. Sirmans, 2002, Diversification benefits from foreign real estate investments, Journal of Real Estate Portfolio Management, 8, 1, 17-25

[50] Cotter J., and S. Stevenson, 2006, Multivariate Modeling of Daily REIT Volatility, *Journal of Real Estate Finance and Economics*, 32:305-325

[51] Davidson, R., and J.G. MacKinnon, 1993, Estimation and Inference in Econometrics, *London: Oxford University Press*

[52] Dickey, D.A., and W.A. Fuller, 1979, Distribution of the estimators for autoregressive time series with a unit root, *Journal of the American Statistical Association*, 74, 427-431

[53] Dickey, D.A., and W.A. Fuller, 1981, Likelihood ratio statistics for autoregression time series with a unit root, *Econometrica*, Vol. 49

[54] Duan, J.C., I. Popova, and P. Ritchken, 2002, Option pricing under Regime Switching, *Quantitative Finance*, 2, 1-17

[55] Ederington, L.H., 1979, The hedging performance of the new futures markets, *Journal of Finance*, 34, 157-170

[56] Eichholtz, P., 1996, Does international diversification work better for real estate than for stocks and bonds? *Financial Analyst Journal*, 52(1): 56–62

[57] Eichholtz, P., 1997a, Real estate securities and common stocks: A first international look, *Real Estate Finance*, 14, 1, 70–74

[58] Eichholtz, P., 1997b, How to invest internationally: region and property type on a global scale, *Real Estate Finance*, 14, 3, 51–56

[59] Eichholtz, P., R. Mahieu, and P. Schotman, 1993, Real estate diversification: by country or by continent? *Working paper*, Limburg University, Maastricht

[60] Eichholtz, P., R.Huisman, K. Kees, and L. Schuin, 1998, Continental factors in international real estate returns, *Real Estate Economics*, 26 (3), 493-509

[61] Eichholtz, P., K. Kees, and M. Schweitzer, 2001, Global property investment and the costs of international diversification, *Journal of International Money and Finance*, 20, 349-366

[62] Eichholtz, P. and K. Koedijk, 1996, The global real estate securities market, *Real Estate Finance*, 13, 1, 76–82

[63] Engel, C., 1994, Can the Markov Switching model forecast exchange rates?, *Journal of International Economics*, 1994, 151-65

[64] Engle, R.F., 1982, Autoregressive conditional heteroskedasticity with estimates of the variance of UK, *Econometrica*, 50, 987-1008

[65] Engle, R.F., 2001, GARCH 101: The use of ARCH/GARCH models in Applied Econometrics, *The Journal of Economic Perspectives*, Vol. 15, No. 4, 157-168

[66] Engle, R.F., 2002, Dynamic conditional correlation – A simple class of multivariate GARCH models, *Journal of Business and Economic Statistics*, 20, 339-350

[67] Engle, R.F., and C.W.J. Granger, 1987, Co-integration and error correction: Representation, estimation, and testing, *Econometrica*, 55, 251-76

[68] Engle, R.F., and J.D. Hamilton, 1990, Long swings in the dollar: Are they in the data and do markets know it?, *American Economic Review*, 80, 689-713

[69] Engle, R.F., and K.F. Kroner, 1995, Multivariate simultaneous Generalized ARCH, *Econometric Theory*, 11,122-150

[70] Engle, R., D.M. Lilien, and R.P. Robins, 1987, Estimating time varying risk premia in the term structure: The ARCH-M model, Econometrica, Vol. 55, 391-407

[71] Engle, R.F., V. Ng, and M. Rothschild, 1990, Asset pricing with a factor ARCH covariance structure: Empirical estimates for treasury bills, *Journal of Econometrics*, 45, 213-238

[72] Eun C.S. and S. Shim, 1989, International Transmission of Stock Market Movements, *Journal of Financial and Quantitative Analysis*, Vol.24, 241-256

[73] Filardo, A. J., 1994, Business cycle phases and their transitional dynamics, *Journal of Business and Economic Statistics*, 1994, 12:3, 299-308

[74] Fisher, J.D. and R.B. Webb, 1992, Current issues in the analysis of commercial real estate, *Journal of the American Real Estate and Urban Economics Association*, 20:1, 211-227

[75] French K.R., Schwert G.W., and Stambaugh R.E., 1987, Expected stock returns and volatility, *Journal of Financial Economics*, 19, 3-29

[76] Gallagher L.A., and C.E. Twomey, 1998, Identifying the source of mean and volatility spillovers in Irish equities: A multivariate GARCH analysis, *Economic and Social Review*, 29, 341-356

[77] Gallo G.M., and E. Otranto, 2005, Volatility transmission in financial markets: A new approach, *Working Paper*

[78] Garcia R., and P. Perron, 1996, An analysis of the real interest rate under regime shifts, *Review of Economics and Statistics*, 78, 111-125

[79] Garvey, R., G. Santry, and S. Stevenson, 2001, The linkages between real estate securities in the Asia-Pacific, *Pacific Rim Property Research Journal*, Vol 7, No 4

[80] Gerlach R., P. Wilson, and R. Zurbruegg, 2006, Structural breaks and diversification: The impact of the 1997 Asian financial crisis on the integration of Asia-Pacific real estate markets, *Journal of International Money and Finance* 25, 974-991

[81] Giliberto, S., 1990, Global real estate securities: Index performance and diversified portfolios, *Salomon Brothers, Inc.*

[82] Glosten, L., R. Jagannathan and D. Runkle, 1993, On the relation between the expected value and the volatility of the nominal excess return on stocks, *Journal of Finance*, Vol. 48, 1779-1801

[83] Goodwin, T.H., 1993, Business-cycle analysis with a Markov Switching model, *Journal of Business & Economics Statistics*, 11, 331-339

[84] Gordon, J. T. Canter, T. and J. Webb, 1998, The effects of international real estate securities on portfolio diversification, *Journal of Real Estate Portfolio Management*, 4, 2, 83–92

[85] Gordon, J. and T. Canter, 1999, International real estate securities: A test of capital markets integration, *Journal of Real Estate Portfolio Management*, 5, 2, 161–170

[86] Gradflund, A., 2000, Are the Nordic stock markets mean reverting?, *Working Paper*, Lund University

[87] Gray, S.F., 1996, Modeling the conditional distribution of interest rates as a Regime-Switching process, *Journal of Financial Economics*, 42, 27-62

[88] Hamao, Y.R., R.W. Masulis, and V.K. Ng, 1990, Correlation in Price changes and Volatility across International Stock Markets, *The Review of Financial Studies*, Vol. 3, 281-307

[89] Hamelink, F., M. Hoesli, and B. Macgregor, 1997, Inflation hedging vs. Inflation protection in the US and the UK, *Real Estate Finance*, 14, 2, 63–73

[90] Hamelink, F., and M. Hoesli, 2002, What factors determine international real estate security returns? *Paper presented at the Annual Meetings of the European Real Estate Society*, Glasgow, Scotland

[91] Hamilton, D., 1989, A new approach to the economic analysis of nonstationray time series and the business cycle, *Econometrica*, 57, 357-384

[92] Hamilton, D., and G. Lin, 1996, Stock market volatility and the business cycle, *Journal of Applied Econometrics*, 11, 5, 573-593

[93] Higgs, H., and Worthington, A.C., 2004, Transmission of returns and volatility in art markets: a multivariate GARCH analysis, *Applied Economics Letters*, 11, 217-222

[94] Hill, J., and T. Schneeweis, 1981, A note on the hedging effectiveness of foreign currency futures, *Journal of Futures Markets*, 1, 659-664

[95] Hudson-Wilson, S. and J. Stimpson. 1996, Adding US real estate to a Canadian portfolio: does it help? *Real Estate Finance,* 12(4): 66–78

[96] Inoue, A., 1996, Tests of cointegrating rank with a trend-break, *Journal of Econometrics*, 90, 215-237

[97] Johansen, S., 1988, Statistical analysis of cointegration vectors, *Journal of Economic Dynamics and Control*, 12, 231-254

[98] Johansen, S., 1991, Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models, *Econometrica*, 59, 1551-1580

[99] Johansen, S., 1994, The role of constant term in the cointegration analysis of non-stationary variables, *Econometric Reviews*, 13, 205-219

[100] Johansen, S. and K. Juselius, 1990, The full information maximum likelihood procedure for inference on cointegration – With applications to the demand for money, *Oxford Bulletin of Economics and Statistics*, 52, 169-210

[101] Johansen, S. and K. Juselius, 1991, Testing structural hypothesis in a multivariate cointegration analysis of the PPP and UIP for UK, *Journal of Econometrics*, 53, 211-244

[102] Kallberg, J., H. Crocker, and P. Pasquariello, 2002, Regime shifts in Asian equity and real estate markets, Real Estate Economics 30(2), 263-291

[103] Kanas, A., 1998, Volatility spillovers across equity markets: European evidence, *Applied Financial Economics*, 8, 245-256

[104] Kim, C.J., and C.R. Nelson, 1998, Business cycle turning points, a new coincident index, and tests of duration dependence based on a dynamic factor model with Regime Switching, *Review of Economics and Statistics*, 80, 188-201

[105] Kim, K.-H., 2000. Korea: could a real estate price bubble have caused the economic crisis? In: Koichi, M., Renaud, B. (Eds.), Asia's Financial Crisis and the Role of Real Estate. Sharpe, M.E., London

[106] King, M. and S. Wadhwani, 1990, Transmission of volatility between stock markets, *Review of Financial Studies*, 3, 5-33

[107] King, M., E. Sentana and S. Wadhwani, 1994, Volatility and links between national stock markets, *Econometrica*, July, 901-33

[108] Kleiman, R. and E. Farragher, 1992, Investment characteristics of international real estate equities, *Real Estate Review*, 22, 3, 33–39

[109] Koutmos G., 1996, Modeling the dynamic interdependence of major European stock markets, *Journal of Business Finance and Accounting*, 23, 975-988

[110] Koutmos G., and G.G. Booth, 1995, Asymmetric volatility transmission in international

stock markets, *Journal of International Money and Finance*, 14, 747-762

[111] Krolzig, H.M., 1997, Markov-switching Vector Autoregressions: Modeling, statistics inference and application to business cycle analysis, Berlin:Springer

[112] Kroner, K.F., and S. Claessens, 1991, Optimal dynamic hedging portfolios and the currency composition of external debt, *Journal of International Money and Finance*, 10,131-148

[113] Kroner, K.F., and J. Sultan, 1993, Time varying distributions and dynamic hedging with foreign currency futures, *Journal of Financial and Quantitative Analysis*, 28, 35-551

[114] Kroner, K.F., and V.K. Ng, 1998, Modeling asymmetric comovements of asset returns, *The Review of Financial Studies*, 11:4, 817-844

[115] Kwiatkowski, D., P.C.B. Phillips, P. Schmidt, and Y. Shin, 1992, Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?, *Journal of Econometrics*, 54, 159-178

[116] Lee, H.S., 2004, International transmission of stock market movements: a wavelet analysis, *Applied Economics Letters*, 11, 197-201

[117] Liow, K.H., K.H. Ho, and Z.W. Chen, 2006, Correlation dynamics in international real estate security markets, *Working Paper, Department of Real Estate*, National University of Singapore

[118] Liow, K.H., J. Ooi, and Y.T. Gong, 2003, Cross-market dynamics in property stock markets: Some international evidence, *European Real Estate Society Conference 2003*

[119] Liow, K.H., and H. Zhu, 2005, Causality in mean and variance: Evidence from real estate markets, National University of Singapore, *Working Paper*

[120] Liow, K.H., H. Zhu, K.H.D. Ho, and A-D. Kwame, 2005, Regime IIIhanges in international securitized property markets, *Journal of Real Estate Portfolio Management*, 11, 2, 147-167

[121] Liu, C., D. Hartzell, and M. Hoesli, 1997, International evidence on real estate securities as an inflation hedge, *Real Estate Economics*, 25,2, 193–221

[122] Liu, C.H., and J. Mei, 1998, The predictability of international real estate markets, exchange rate risks and diversification consequences, *Real Estate Economics*, 26 (1), 3-39

[123] Liu Y.A., and M. Pan, 1997, Mean and volatility spillover effects in the US and

Pacific-Basin stock markets, *Multinational Finance Journal*, 1, 47-62

[124] Liu, J., S. Wu, and J.V. Zidek, 1997, On segmented multivariate regressions, *Statistica Sinica*, 7, 497-525

[125] Lizieri, C., P. Mcallister, and C. Ward, 2002, Continental shift? An analysis of convergence trends in European real estate equities, *Paper presented to the American Real Estate Society Annual Meeting*, Naples, FL, April

[126] Lizieri, C., S. Satchell, E. Worzala, and R. Dacco, 1998, Real interest regimes and real estate performance: A comparison of U.K. and U.S. markets, *Journal of Property Research*, 16:3, 339-55

[127] Longin, F. and B. Solnik, 1995, Is the international correlation of equity returns constant: 1960-1990?, *Journal of International Money and Finance*, February, 3-26

[128] Longin, F., and B. Solnik, 1998, Correlation structure of international equity markets during extremely volatile periods, *Working paper*, HEC School of Management

[129] Maitland-Smith, J. K. and C. Brooks, 1999, Threshold autoregressive and Markov Switching models: An application to commercial real estate, *Journal of Property Research*, 16:1, 1-19

[130] Manning, N., 2002, Common trends and convergence? South east Asian equity markets, 1988-1999, *Journal of International Money and Finance*, 21(2), 183-202

[131] Markowitz, H.M., 1959, Portfolio selection: Efficient diversification of investment, John Wiley & Sons, New York

[132] Martens, M., and S. Poon, 2001, Returns synchronization and daily correlation dynamics between international stock markets, *Journal of Banking and Finance*, 25,10, 1805–1827

[133] Maurer, R. and F. Reiner, 2002, International asset allocation with real estate securities in a shortfall risk framework: The view point of German and US investors, *The Journal of Real Estate Portfolio Management*, 8, 1, 27–43

[134] Michayluk D., P.J. Wilson, and R. Zurbruegg, 2006, Asymmetric volatility, correlation and returns dynamics between the U.S. and U.K. securitized real estate markets, *Real Estate Economics*, V34 1:109-131

[135] Michelfelder R.A., 2005, Volatility of Stock Returns: Emerging and Mature Markets, *Managerial Finance*, Vol 31, No.2, 66-86

[136] Morimune K., and M. Nakagawa, 1997, Unit root tests which allow for multiple breaks, *Discussion Paper No. 457, Kyoto Institute of Economic Research*, Kyoto University

[137] Mull, S. and L. Soenen, 1997, U.S. REITs as an asset class in international investment portfolios, *Financial Analysts Journal*, 53, 2, 55–61

[138] Myer, F.C., N.M. Chaudhry, and J. Webb, 1997, Stationarity and co-integration in systems with three national real estate indices, *Journal of Real Estate Research* 13(3), 369-381

[139] Nelson, C.R., and C.I. Plosser, 1982, Trends and random walk in macroeconomic time series, *Journal of Monetary Economics*, 10, 139-162

[140] Nelson, D., 1991, Conditional heteroskedasticity in asset returns: A new approach, *Econometrica*, 59, 347-370

[141] Newly, W.K. and K.D West, 1987, A Simple, positive semidefinite, heteroskedasticity and auto-correlation consistent covariance matrix, *Econometrica*, 55, 703-708

[142] Otranto, E., 2005, The multi-chain Markov Switching model, *Journal of Forecasting*, 24, 523-537

[143] Parkinson, M., 1980, The extreme value method for estimating the variance of the rate of returns, *Journal of Business*, 53, 61-65

[144] Parron, P., 1989, The great crash, the oil price shock, and the unit root hypothesis, *Econometrica*, 57(6), 1361-1401

[145] Pesaran, M. H., Y. Shin and R. J. Smith, 1996, Testing for the existence of a long run relationship, *DAE Working Paper No 9622*, Dept of Applied Economics, University of Cambridge

[146] Pesaran, M. H. and Y. Shin, 1998, An autoregressive distributed lag modeling approach to cointegration analysis, *DAE Working Paper No 9514*, Dept of Applied Economics, University of Cambridge

[147] Phillips, P.C.B., and P. Perron, 1988, Testing for a unit root in time series regression, *Biometrica*, 75, 395-346

[148] Pierzak, E., 2001, Exploring international property securities for us investors, *Henderson Global Investors Property Economics & Research*

[149] Pindyck R., 1984, Risk, inflation, and the stock market, *American Economic Review*, 76, 335-351

[150] Poon S.H., and C.W.J. Grange, 2003, Forecasting Volatility in Financial Markets: A Review, *Journal of Economic Literature*, Vol. XLI, 478-539

[151] Quintos, C.E., 1998, Fully modified vector autoregressive inference in partially nonstationray models, *Journal of the American Statistical Association*, 93, 783-795

[152] Renaud, B., 2000, How real estate contributed to the Thailand financial crisis. In: Koichi, M., Renaud, B. (Eds.), Asia's Financial Crisis and the Role of Real Estate. Sharpe, M.E., London

[153] Renaud, B., M. Zhang, and S. Koeberle, 2001, Real estate and the Asian crisis: lessons of the Thai experience. In: Brown, S.B., Crocker, H.L. (Eds.), A Global Perspective on Real Estate Cycles. Kluwer, Boston

[154] Schaller, H., and S. Van Norden, 1997, Regime Switching in stock market returns, *Applied Financial Economics*, 7, 177-191

[155] Scheicher, M., 2001, The comovements of stock markets in Hungary, Poland and the Czech Republic, *International Journal of Finance and Economics*, 6:27-39

[156] Shapiro, M., and M. Watson, 1988, Sources of business cycle fluctuations, *NBER Macroeconomics Annual*, 3, 111-148

[157] Sinquefield, R. A., 1996, Where are the gains from international diversification?, *Financial Analysts Journal*, January/ February, 8-14

[158] Solnik, B., 1974, Why not diversify internationally rather than domestically?, *Financial Analysts Journal*, July/August, 48-54

[159] Stevenson, S., 1999, Real estate's role in an international multi asset portfolio: Empirical evidence using Irish data, *Journal of Property Research*, 16, 3, 219–242

[160] Stevenson, S., 2000, International real estate diversification: empirical tests using hedged indices, *Journal of Real Estate Research*, 19, 1/2, 105–131

[161] Suliman, O., 2005, Interest rate volatility, exchange rates, and external contagion, *Applied Financial Economics*, 15, 883–894

[162] Susmel R., and R.F. Engle, 1994, Hourly volatility spillovers between international equity markets, *Journal of International Money and Finance*, 13, 3-25

[163] Sweeney, F., 1993, Mapping a European property investment strategy, *Journal of Property Valuation and Investment*, 11, 259-267

[164] Tarbert, H., 1998, The long-run diversification benefits available from investing across geographic regions and property type: evidence from cointegration tests, *Economic Modelling*, 15, 49-65

[165] Tay, N.S.P., and Z. Zhu, 2000, Correlations in returns and volatilities in Pacific-Rim stock markets, *Open Economies Review*, 11:27-47

[166] Theodossiou P., and U. Lee, 1993, Mean and volatility spillovers across major national stock markets: Further empirical evidence, *The Journal of Financial Research*, Vol. XVI, No.4

[167] Theodossiou P., and U. Lee, 1994, Relationship between volatility and expected returns across international stock markets, *Journal of Business Finance and Accounting*, 21

[168] Tsay, R.S., 2005, Analysis of financial time series, 2nd Edition, Wiley-Interscience

[169] Tse, Y.K., 2000, A test for constant correlations in a multivariate GARCH model, *Journal of Econometrics*, 98:107-127

[170] Tse, Y.K., and A.K.C. Tsui, 2002, A multivariate generalized autoregressive conditional heteroscedasticity model with time-varying correlations, *Journal of Business and Economic Statistics*, 20, 351–362

[171] Von FGM, and B.N. Jeon, 1989, International Stock Price Movements: Links and Messages, *Brookings Papers on Economic Activity*, Vol. 1, 125-179

[172] Wilson, P., and J. Okunev, 1999, Long-term dependencies and long-run non-periodic co-cycles: Real estate and stock markets, Journal of Real Estate Research, 18, 2, 257-278

[173] Wilson, P. and R. Zurbruegg, 2003a, Isolating important driving forces in indirect real estate markets, *Journal of Real Estate Portfolio Management*, 9, 205-218

[174] Wilson, P. and R. Zurbruegg, 2003b, International diversification of real estate assets – Is it worth it? Evidence from the literature, *Journal of Real Estate Literature*, 11, 259-278

[175] Wilson, P. and R. Zurbruegg, 2003c, Can large economies drive international real estate markets, *Pacific Rim Property Research Journal*, 9, 379-397

[176] Wilson, P., and R. Zurbruegg, 2004, Contagion or interdependence? Evidence from comovements in Asia-Pacific securitised real estate markets during the 1997 crisis, *Journal of Property Investment & Finance*, 22, 401-413

[177] Wilson, P., S. Stevenson and R. Zurbruegg, 2007, Foreign property shocks and the impact on domestic securitized real estate markets: An unobserved components approach, *Journal of Real Estate Finance and Economics*,34, 407-424

[178] Worzala, E., and C.F. Sirmans, 2003, Investing in international real estate stocks: A review of the literature, *Urban Studies*, 40, 5-6, 1115-1149

[179] Ziobrowski, A.J., and R.J. Curcio, 1991, Diversification benefits of U.S. real estate to foreign investors, *Journal of Real Estate Research*, 6, 119-142

[180] Zivot, E., and D. Andrews, 1992, Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis, *Journal of Business and Economic Statistics*, 10, 3, 251-270